Electrochemical and Metallurgical Industry

NEW YORK, NOVEMBER, 1909.

CONTENTS.

New York Meeting American Electrochemical Society.

On another page will be found the very interesting program of the autumn meeting of the American Electrochemical Society, to be held according to the custom of recent years in New York City. The program of papers is very full, almost too full for three sessions, and includes an experimental lecture of general interest by Dr. Edgar F. Smith, on advances in electrochemical analysis, in which field he has done such revolutionary work. From abroad a paper has been contributed giving the latest information on the Badische Company's new process of fixation of atmospheric nitrogen, which, as our readers know, has aroused so much interest. There is a goodly number of papers on electric furnaces, on electrolytic processes, and on metallurgical subjects. We also notice not less than three papers on dry cells. The smallness of the dry cell makes most people overlook the importance of this industry; but a reliable estimate made a few years ago of the number of dry cells used in this country gave not less than 30,000,000 to 50,000,000 per year. The program of the papers appears to be well balanced with respect to the different fields covered by the authors. It would be regrettable, however, if the large number of papers—there being 22 announced—would prevent their adequate discussion.

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The program of the entertainments is very attractive. The social features have always been prominent in the conventions of the Electrochemical Society and have always been greatly enjoyed. We may be sure that the coming meeting will be no exception. A whole day has been set aside for the excursion to the Bayonne chemical and metallurgical industries. Not less than eight plants will open their doors to the society, and the excursion promises to become the most interesting that has ever been made by a technical society to this rapidly growing industrial center in New Jersey. With the regrettable exception of one interesting metallurgical works all other important companies have extended their invitations to the society. To Mr. T. J. Parker is due chiefly the credit for having prepared, with great trouble, this attractive program. At the professional sessions the society will be the guest of Columbia University and of the Chemists' Club. The Chemists' Club will also be the host of the society at one of its famous smokers on Saturday night; and on this occasion "section Q" should find its opportunity.

The Dry Blast Process.

In this issue we publish a paper presented by Mr. R. S. Moore at the recent meeting of the Iron and Steel Institute, on the fuel economy of dry blast as indicated by calculations from empirical data, in which he stated and argued very clearly and convincingly the principle that "removing the moisture before it enters the furnace is equivalent to utilizing a corresponding amount of heat in melting the iron and fusing the slag." Since these two items only get some 18 per cent of the total heat

generated in the furnace, and since this usefully applied heat is really the governor of the whole furnace running, the criterion of its efficiency, it follows that every 1 per cent of the heat of the furnace saved to the tuyere region or smelting-down zone represents $1/18th = 5.5$ per cent saving of fuel to the furnace. This is exactly the view which has been repeatedly advocated in the columns of this journal, and in our reviews of this subject. We agree entirely also with Mr. Moore's comparison of the saving effected by hot blast and that by dried blast; the two are directly analogous and comparable.

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Mr. Moore, however, states that "it is a well-known fact that for the economical reduction of iron oxide in the blast furnace, as large a proportion as possible must be reduced by carbon monoxide." Here Mr. Moore lays down a dictum which is only a partial truth, and which is often wrong. When well-dried blast is used, for example, a furnace works very economically and a smaller proportion of the reduction is done by the reducing gas, as can be conclusively proved by analyzing the running of the furnace. Mr. Moore is thus led astray in his further consideration of the modus operandi of hot blast, and ends by concluding that uniformity in the mixture content is a more potent factor in the economy of the furnace than low moisture content. In the discussion it was brought out that the Dowlais furnace working on dried blast had shown an increased output of 15 per cent, the Cardiff furnace a diminished coke consumption of 17 per cent; also that the United States Steel Corporation was operating three furnaces on dried blast, had plans made for three more, and was preparing plans for 20 others.

Subway Air.

Ever since the New York Subway was opened, there have been complaints concerning its depressing atmosphere. In a recent letter to the New York *Times,* Mr. John T. Morrow writes: "The majority of us have had the experience of entering a subway train feeling fresh and full of vigor, and emerging from the same train in a few minutes feeling stupid and depressed. This is simply due to the fact that we have been breathing, over and over again, air far too low in oxygen to be of proper use to our lungs, and at the same time containing tremendous quantities of bacteria in suspension." Mr. Morrow proposes the use of ozone for the purification of the air. He suggests that several ozone apparatus of small size be placed in each car of subway trains and connected to the electric lighting circuit. The ozone would destroy not only a large portion of germ life, but Mr. Morrow thinks that the larger amount of oxygen in the air, produced thereby, would have a stimulating rather than depressing effect on the passengers. The experiment would be well worth trying. The cost would be chiefly the first cost of the ozone apparatus and accessories (converters and high-tension transformers). Aside from maintenance and repairs, the cost of operation would be practically nihil. That the ozone would be effective in destroying bacteria by oxidation, there can be no doubt. The only question is where to take a new supply of oxygen from. Of course, if ozone apparatus are installed in a subway car, they can do nothing but transform the oxygen which is present in the air in the car into ozone, according to the equation: $3O_2 = 2O_3$.

They cannot create new oxygen. In Europe, where oxygen apparatus are used on a larger scale than in this country for the purification of air in buildings, the practice is to install a combination of fan and ozone apparatus in a hole in the wall, so that fresh air is constantly supplied from the outside into the building and at the same time the oxygen is transformed into ozone. Some similar arrangement has been suggested for mine ventilation, where the ozone apparatus with ventilator would be installed at the top of a shaft. (Obviously for safety means, the use of ozone is impossible in coal mines.) If ozone apparatus is to be installed on subway trains, they must be used in connection with fans which supply fresh air from the tunnel into the inside of the cars. How far this will be successful can only be found out by experiment.

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A few years ago Dr. R. Von Foregger suggested the use of fused sodium peroxide for the same purpose. The scheme is ingenious; it is based upon the reaction between sodium peroxide and water. This yields sodium hydroxide and oxygen. Thus we get a fresh supply of oxygen. But more than that, the sodium hydroxide produced will absorb the carbon dioxide given out from the lungs of the passengers. The method, therefore, yields not only fresh oxygen for the lungs, but takes care of the carbon dioxide given out by the lungs, thus regenerating the air in correct proportions. The method has been successfully used in connection with submarine boats, in case of mine accidents, etc. Whether it could be used on subway trains with commercial success is chiefly a question of cost. The first cost of apparatus would probably be less than with ozone apparatus, but the cost of operation would be high, due to the large quantities of sodium peroxide which would be consumed. The fact that gradually all passenger traffic to the business section of New York—whether from northern Manhattan or New Jersey or Long Island—will be carried out through tunnels, renders the problem an important one for public health. The fact of the existence of a Public Service Commission makes it probable that some day something will be done to remedy the conditions. So much has been accomplished in recent years in developing new methods of producing oxygen gas cheaply for autogenous welding, that we may hope an effective and fairly inexpensive solution of the purification of subway air will also be found if the above suggestions should prove impractical for some reason.

Commercial Efficiency.

In the discussion of the relative merits and demerits of any process or machine there is always more or less talk about its efficiency. But, as Mr. James Swinburne once remarked, efficiency is a common by-word of the professional politician and reformer. Engineers should rather speak of efficien*cies* and define in each case what particular ratio of the actual to the ideal quantity they mean. Thus, in the production of caustic soda and chlorine by electrolysis of a common salt solution, we may consider the electrolytic cell alone and speak of its amp-hour efficiency, which, in general, will not be the same for the production of chlorine as for the production of caustic soda. In either case it represents the ratio of the real output to the ideal output which, according to Faraday's law, would be obtained if the electric current produced nothing but the desired reaction.

Or, we may speak of the watt-hour efficiency of the cell, which gives the ratio of the actual output to the ideal output, which would be obtained, if all electrical energy had been transformed into chemical energy producing the desired reaction.

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But for commercial purposes it is necessary to take a wider view. The electrolytic cell is only one part of the whole installation, and the commercial object must be to make as much money out of the given total installation as possible. This is to a certain degree possible by pushing the output of the whole plant at the expense of the efficiency of the electrolytic cells. This fact was very well brought out in the paper of Dr. Baekeland on three years' practice of the Townsend cell, published in our July issue. Running with a density of 100 amp per square foot, a current efficiency of 97 per cent or 98 per cent can be attained. Running with a density of 150 amp per square foot the current efficiency is only 95 per cent. But the fact that the output of the plant is thus increased 50 per cent with the same interest on plant and the same cost of the operating staff, while the cost of repairs and cost of power have been but slightly increased, makes it good business to increase the capacity of plant at the sacrifice of the highest perfection of technical economy. In general, the money-making ability of a plant may be considered as the product of technical efficiency (intensity factor) and output (capacity factor), just as the power of a waterfall is the product of the height of the fall and of the quantity of water.

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The same principle was used by Mr. Carnegie in the conduct of his steel business. It should not be lost sight of now by electrometallurgists when the electric furnace enters the immense field of production of structural steel. As we have often pointed out, what makes the future of the electric steel furnace most promising is the fact that in recent years consumers have insisted more and more on better steel and have become accustomed to favor open-hearth steel very decidedly over Bessemer steel. The danger that Bessemer plants would become useless in time did exist. It is here that the electric furnace has an immense field of usefulness if as an adjunct to the converter it can make steel of open-hearth or better quality at the same cost or more cheaply. It thereby gives the converter a new lease of life. It forms in this case a link between converter plant and rolling mill. Naturally, at present, the electric furnace is still the weakest link in the chain. To run the whole plant at maximum efficiency, the first and most important requirement is to make the electric furnace as reliable in operation and as uniform in production as the two other ends of the chain—the converter plant and the rolling mill. Simple, strong and reliable construction of the electric furnace are now of main importance, even if the efficiency is somewhat lower or some materials of construction are more expensive. There will be much to do later on for the designer to improve details in design, when once the electric furnace has conquered the steel field by simple and most ordinary reliability of operation.

The Stupendous Rate of Recovery of the Iron Industry.

The production of pig iron in the United States has reached a new record rate in the past two months, having easily passed the 30,000,000-ton mark, the best rate attained previous to this movement having been 28,000,000 tons, in October, 1907, while the best output for 12 consecutive months was about 27,150,000 tons, in the 12 months ending Oct. 31, 1907. It is difficult to grasp the magnitude of the swings in production, for, meanwhile, in January, 1908, the rate of pig-iron production dropped to not over 13,000,000 tons. Expressed in terms of value the variations are more impressive. Pig iron itself, of course, is nothing; it is merely the raw material of the iron foundry or the steel mill. The tonnage of finished product, in the form of iron and steel castings, and rolled and forged iron and steel, slightly exceeds the tonnage of pig iron, for the decrement in actual loss of iron and elimination of metalloids, which are weighed in the pig iron but do not appear in the finished product, is more than made up by the increment due to the re working of old material and the use of ore in the open-hearth steel furnace. Taking it all in all, the average value of the finished product of the iron and steel industry probably lies not far from $40 a ton, so that a change of a single million tons a year in the rate of pig-iron output means a change of not far from $40,000,000 a year in the value of the industry's output.

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Notwithstanding the great excess over the last high record rate the iron industry is not yet employing its maximum capacity, so great has been the increase in the past two years. In our issue of January, 1908, we reviewed the course of the industry in 1907, observing that a rate of 28,000,000 tons a year had been reached in October, while at Jan. 1, 1908, there was new furnace capacity under construction amounting to 3,500,000 tons annually. While October is normally a record-breaking month, so that the performance of that month could not by itself be taken as proof of the possibility of maintaining the rate for a year, the fact was that a number of furnaces had played out on account of the strain of a campaign of almost three years of steady driving, and the actual capacity at the close of the year was really about 28,000,000 tons. Since then the greater part of the 3,500,000 tons of new erection has been brought to completion, and while the actual rate of production exceeds 30,000,000 tons a year, there are statistics which show that the merchant blast furnaces are not making as much pig iron as they did in 1907, although there have been some accretions to their ranks. Additional blast furnaces have been projected since Jan. 1, 1908, and the industry is making for a capacity, by next midsummer, of between 32,500,000 and 33,-000,000 tons.

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Stupendous as are these increases, they are but in line with the precedents of the industry. Decade after decade the industry has doubled its output. Obviously, the breaking down of the geometrical rule of progression must come some time, but the time is not in sight. Presumably the rule will break down as to pig iron sooner than it will as to the production of finished material, for the reason that larger and larger tonnages of old material will come back for reworking. Thus far our store of iron is too new for much of it to require reworking, and the tonnage of old material coming out each year is quite modest. Fully one-half of all the pig iron which has been made in the United States has been produced in the past 10 years, and considerably more than three-fourths in the past 20 years. Despite its present size the industry is really very new.

New York Meeting of American Electrochemical Society.

The autumn meeting of the American Electrochemical Society will be held in New York City on Oct. 28, 29, and 30.

A session for the reading and discussion of papers will be held in the afternoon of Thursday, Oct. 28, at the Chemists' Club, beginning at 1:30 p. m. Two sessions for the reading and discussion of papers will be held on Saturday in Earle Hall, Columbia University, one beginning in the morning at 9:30 and the other in the afternoon at 2 o'clock. The whole of Friday will be spent in an excursion to the chemical and metallurgical industries of Bayonne, N. J.

Friday evening a subscription dinner will be held at the Hotel Cumberland. On the evening of Saturday the society will be the guests of the Chemists' Club at a smoker in their clubhouse. Hotel headquarters are at the Cumberland, Fifty-fourth Street and Broadway.

The program for the **excursion on Friday** is as follows:

Members and guests will meet in the waiting-room of the station of the Central Railroad of New Jersey in Jersey City at 8.30 a. m. (This station can be reached from New York by ferries either from Liberty Street or Twenty-third Street, not from New York in any other way.)

A special train will take the party to the Constable Hook section in Bayonne, where the forenoon will be spent. In the afternoon plants in the Newark Bay section of Bayonne will be visited.

At noon a lunch will be served at one of the shore resorts on the Kill von Kuhl. The Mayor of Bayonne, Hon. Pierre P. Garven, will there welcome the society to Bayonne.

The following companies have given permission to visit their plants:

Standard Oil Company (oil refineries).

National Sulphur Company (refining of sulphur).

Pacific Coast Borax Company (manufacturers of borax and boric acid).

Gröndal briquetting plant at the works of the General Chemical Company. (The first American installation of the Gröndal process.)

Babcock & Wilcox Company (water-tube boilers and adjuncts).

Electro-Dynamic Company (interpole motors for wide-speed variation).

Electric Launch company (submarine vessels, etc.).

Industrial Oxygen Company (oxy-acetylene welding and cutting apparatus).

The party will return to New York by special train in time for the banquet in the evening.

It is to be clearly understood that while the above-named companies have given permission to the society as a whole to visit their works, members interested in a competitive process are expected not to visit that particular plant. Thus, the Standard Oil Company has given permission under the condition that no one connected with the refining of oil will be allowed to visit their works. Similar conditions have been made by the Babcock & Wilcox Company, the Pacific Coast Borax Company, and the National Sulphur Company. The different plants are, however, of such a diversified character that every member will find it profitable to take part in the excursion.

Railroad tickets for the excursion will be distributed to members and guests when registering.

Admittance to plants to be visited will be granted only to members and guests wearing the society badge.

Since a special program has been arranged for entertaining the ladies on Friday, ladies are not expected to take part in the excursion to Bayonne.

The **program of papers** to be presented at the three sessions is as follows:

Thursday Session.

The Titanium Arc. By W. S. Weedon.

The Element Boron. By E. Weintraub.

A New Electrolytic Method for the Preparation of Explosive Antimony. By R. C. Palmer.

Advances in Electrochemical Analysis. By Dr. Edgar F. Smith. (This is an experimental lecture to be held on special invitation by the board of directors. It is scheduled at 3 p. m.)

Saturday Morning Session.

The Preparation of Silundum. By S. A. Tucker, H. F. Kudlich and E. M. Heumann.

The Laws of Electrode Losses in Electric Furnaces. By Carl Hering.

Furnace Electrode Losses. By C. A. Hansen.

Electrode Losses and Furnace Efficiency. By E. F. Roeber.

A New Method of Measuring Mean Thermal and Electrical Conductivities of Electrodes. By Carl Hering.

The Practical Conductance of Electrolytes. By Joseph W. Richards and W. S. Landis.

A New Theory of Corrosion. By Maximilian Toch.

Electrolytic Preparation of Calcium. By F. C. Frary.

Calcium Carbide. By M. de Kay Thompson.

An Electric Furnace for Production of Pig Iron. By Edward R. Taylor.

Saturday Afternoon Session.

Evolution and Present Status of the Dry Cell. By J. W. Brown.

Dry-Cell Tests. By F. H. Loveridge.

Some Characteristics of Dry Cells. By C. F. Burgess and Carl Hambuechen.

The Manufacture of Air-Saltpeter by the Process of the Badische Anilin & Soda Fabrik. By C. Schönherr.

Power for Electrolytic Copper Refining at the Buffalo Smelting Works. By W. L. Spalding.

A Process for Simultaneously Cleaning, Annealing and Zincing Wire by Electrochemical Cementation. By Alfred Sang.

Notes on Zinc, Copper and Brass Dusts. By Alfred Sang.

Alloys of Copper with Electrolytic Iron. By C. F. Burgess and James Aston.

For the **entertainment of ladies** the following program has been arranged:

Thursday afternoon, Oct. 28, ladies' tea and reception at the Waldorf-Astoria, by invitation of Mrs. W. H. Nichols.

For Friday, Oct. 29, the ladies' committee has arranged the following automobile trip for the visiting ladies: Leave Hotel Cumberland at 3 p. m., drive through Central Park, Riverside Drive to Claremont Restaurant, where light tea will be served at 4 p. m. Return to Hotel Cumberland at 5.30 p. m.

Members and guests are invited to bring ladies to the subscription dinner at the Hotel Cumberland, Friday evening.

Ladies are also included in the invitation to lunch on Saturday, Oct. 30, noon, at Columbia University.

On Saturday evening, visiting out-of-town ladies are invited by the ladies' committee to a theater party, leaving Hotel Cumberland at 8 p. m. On the same evening the members of the Society are the guests of the Chemists' Club.

Iron-Ore Industry of Cuba.

The iron ores which have been mined in Cuba up to the present time consist largely of hematite and magnetite and are obtained near Santiago, in the Province of Oriente (Santiago). Recently large deposits of brown ore have been attracting considerable attention, especially those of Mayari and Moa fields in Oriente Province and those of the Cubitas field in Camaguey Province. No ores of this type have been mined, however.

The following table, taken from a report by E. C. Harder, of the United States Geological Survey, issued as an advance chapter from "Mineral resources of the United States, calendar year 1908," shows the shipments of iron ore from Cuba since the opening of the mines in 1884:

SHIPMENTS OF IRON ORE FROM MINES IN THE PROVINCE OF ORIENTE (SANTIAGO), 1884-1908, IN LONG TONS.

1884	25,295
1885	80,716
1886	112,074
1887	94,240
1888	206,061
1889	260,291
1890	363,842
1891	264,262
1892	341,654
1893	351,175
1894	156,826
1895	382,494
1896	412,995
1897	454,285
1898	168,339
1899	377,189
1900	446,872
1901	552,248
1902	699,734
1903	623,621
1904	387,273
1905	561,159
1906	640,574
1907	681,393
1908	819,434

By far the larger proportion of this ore came to the United States, the imports from Cuba in 1908 being 579,668 long tons. This was about three-fourths of the total imports of iron ore; in 1907 Cuba supplied a little more than half the ore imported.

The Iron and Steel Market.

The finished steel trade has been less active in October than in September, as regards buying and specifying, but this appears to have been due to the previous activity, whereby buyers are covered and mills are sold up for a fair distance ahead.

An exception is noted in sheets and tin plates, in which lines order books have been opened for deliveries to April 1, following the advances of 10 cents per 100 lbs. made Sept. 28. The demand in these lines is quite heavy.

Wire and pipe mills adhere to their practice of not selling material beyond that which can be specified for shipment within 60 days, and as bookings had already been heavy the current pace of bookings is below normal.

In plates, bars and shapes the mills are not only filled with specifications practically to the end of the year, but have a large tonnage on books for first quarter delivery. They have become rather reluctant to accept business for first quarter, as a large part of the legitimate demand from consumers is covered, and it is not desired to sell so far ahead to the jobbing trade. For the present quarter they cannot accept much business, being already filled.

The finished material market is taking a breathing spell and does not promise any important developments for a while.

Individual steel mills have been making fresh production records in October, while the industry as a whole has reached a rate of output never before attained. Pig-iron production in October has easily been at a rate of 30,000,000 tons a year, which compares with a maximum rate of 28,000,000 tons a year in 1907, this rate being attained in October of that year. The difference of 2,000,000 tons does not represent the full advance made by the steel trade proper, for the reason that the merchant furnaces, supplying the foundry trade, lack not far from 1,000,000 tons of having reached their former gait, the steel works furnaces having correspondingly increased theirs.

An evidence of the pressure the steel works have been under is found in the large purchases of merchant Bessemer pig iron made lately by five large independents in the Central West—Lackawanna Steel Company, Cambria Steel Company, Jones & Laughlin Steel Company, Republic Iron & Steel Company and Youngstown Sheet & Tube Company. These interests were aligned to be practically self-supporting in the matter of pig iron, but under pressure their steel departments have been making for a rate to which their blast furnaces were unequal. In September and October they have bought merchant Bessemer pig iron for forward delivery to the extent of about 250,000 tons for the fourth and first quarters. In other words, they prepared to consume Bessemer iron at a rate 500,000 tons a year in excess of their own production.

Their combined furnace capacity is about 4,000,000 tons annually.

This movement is quite in keeping with past experiences. Under pressure a steel works shows more flexibility than a blast furnace, while another element is that it is more economical to have an excess of steel making than an excess of pig-iron making capacity, if there must be a difference.

The general trend in railroad buying is toward an increase. This matter of railroad buying is more or less independent of the general purchasing disposition of the country, and in the revival the railroads have been slower than other interests in coming into the market.

Their purchases are steadily increasing, but remain far below the rate in 1906.

Pig Iron.

Bessemer pig iron has continued its advance, having moved from $16.75, valley, to $18 during September, and from $18 to $19 during October. Among important purchases were about 65,000 tons by the Cambria Steel Company at $18 and $18.50, valley, and, later, 20,000 tons by the Republic Iron & Steel Company at $19. The total transactions in Bessemer pig iron since Sept. 1, chiefly at flat prices, but including 38,000 tons on sliding scale contracts and 25,000 tons arranged to be smelted, the consumer furnishing the ore, have amounted to about 350,000 tons, the largest transactions recorded for two consecutive months in many years. Foundry iron has been fairly active in New England, but has been relatively quiet in the Central West. The valley market (90 cents higher delivered Pittsburgh) stands at $19 for Bessemer, $17.25 to $17.50 for basic, $17 to $17.50 for No. 2 foundry, $17.75 to $18 for malleable and $16.25 to $16.50 for forge. The Birmingham market is strong at $15.

Unfinished Steel.

Billets, sheet bars and rods have almost disappeared from the market, producers being so well engaged in their own finishing mills. Chicago reports no market at all, the East has advanced, with very limited offerings, and there are only occasional lots available in the Pittsburgh market. There is inquiry for sheet bars for first quarter delivery, but no sellers have been found as yet. Prices at Pittsburgh may be quoted largely nominal as follows: Bessemer billets, $26; open-hearth, $26 to $26.50; sheet bars, $27 to $28; rods, $32.

Finished Materials.

Prices stand as follows, f. o. b. Pittsburgh except where otherwise noted:

Steel bars, $1.40 to $1.50, base.

Iron bars, $1.60 to $1.65, base; Chicago, $1.50 to $1.55.

Plates, $1.50 to $1.60.

Shapes, $1.50 to $1.60.

Standard rails, $28 for Bessemer and $30 for open-hearth, f.o.b. mill, except Colorado; light rails, 30-lb. to 40-lb., $28.

Sheets, 28 gage, black, $2.30; galvanized, $3.35; corrugated roofing, $1.60 per square for painted, $2.85 for galvanized.

Merchant steel pipe, extreme price, 80 and 5 off list; wrought-iron pipe, 75 and 5 off list.

Plain wire, $1.60; wire nails, $1.80, base; painted barb wire, $1.80; galvanized barb wire, $2.10.

Institute of Metals.

The autumn meeting of the (British) Institute of Metals was held in Manchester on Oct. 14 and 15. Among the papers presented we note the following:

J. H. Andrew and C. A. Edwards, on "the constitution and properties of the ternary alloys aluminium-copper-tin."

C. O. Bannister and H. J. Tabor, on "the surface appearance of solders."

H. W. Greenwood and F. J. Brislee, on "the technical assay of zinc."

J. S. Glen Primrose, on "the production of pure spelter."

E. L. Rhead, on "some causes of the corrosion of copper and brass."

Prof. C. A. M. Smith, on "the elastic breakdown of non-ferrous metals.".

Prof. T. Turner and M. T. Murray, on "the copper-zinc alloys—a study of volume changes during solidification."

Abstracts of some of these papers will be found in the Synopsis in this issue.

Sir William White was the first president of this new society devoted to the metallurgy of non-ferrous metals, while Sir Gerard Muntz is the president-elect. Mr. G. Shaw Scott, Caxton House, Westminster, S. W., London, is the secretary.

Incidental Problems in Gas-Producer Tests.

As part of its investigation of methods for increasing the efficiency of fuel resources, the United States Geological Survey is studying the general problems involved in the economic use of fuels in gas producers. Among many incidental problems of prime importance that have arisen in the course of this study are those of determining, under practically constant conditions, the duration of gas-producer tests necessary to reduce the possible error to a minimum and of determining the differences of temperature in the fuel bed of the gas producer and the influence of such differences on the chemical reactions taking place within the producer.

In attempts to improve the gas producer considerable attention has been given by manufacturers to such problems as those of fixing or isolating the combustible components of the tar, utilizing the waste heat of the producer for the generation of the steam required by the plant, and applying the suction principle to bituminous coal and other tarry fuels. Little study, apparently, has been given to the physical and chemical conditions most suitable to the formation of hydrogen and of carbon monoxide, with a view to regulating the percentages of these gases in generators using fuels other than anthracite coal or charcoal.

Reports on the two problems first stated above are given in Survey Bulletin 393, which can be obtained free of charge by applying to the Director of the Survey at Washington.

The bulletin consists of two papers, one, by R. H. Fernald and C. D. Smith, on the factors affecting the proper length of tests, the other, by J. K. Clement and H. A. Grine, on temperature differences in the fuel bed.

Messrs. Fernald and Smith, summarizing the results of their experiments, state:

"That throughout a test the fuel bed should be maintained in uniform condition, with regard to both the character of the fire and the thickness of the bed.

"That failing in this, special care should be exercised to see that the fuel bed is in the same condition and of the same thickness at the close of a complete test, or end of a test period, as at the beginning.

"That a test should never be started when the producer has been standing idle for some time with 'banked fires,' as the fuel·bed will not be in the average condition under which it will be required to work during the test.

"That if, as the appointed hour for closing the test approaches, the fuel bed is not in the proper condition, the time of closing the test should be postponed until the bed naturally assumes the proper thickness and character. No forcing of conditions should be allowed simply to bring the test to an end at a previously determined hour."

Messrs. Clement and Grine report that:

"Temperature observations were made and gas samples taken in different parts of the fuel bed of the gas producers. The temperature was found to be highest at the bottom of the fuel bed and to decrease from this point to the top of the bed.

"The temperature of the inner region of the fuel bed was found to be 300° or 400° lower than that of the outer layers. A corresponding inferiority in the quality of the gas in the center of the producer could not be established; probably on account of the defective method of sampling.

"It has been suggested that by an improvement in the method of admitting the draft to the fuel bed a more uniform distribution of temperature, and consequently a gain in the capacity of the producer and in the quality of the gas, might be obtained.

"Reference has been made to recent experiments by one of the authors which have established 1300° C. as the lower limit of temperature for the formation of a gas rich in CO."

CORRESPONDENCE.

Graphite Electrodes.

To the Editor of Electrochemical and Metallurgical Industry:

Sir:—In my article on furnace electrode losses which appeared in your August issue, I made the statement that graphite electrodes could not be purchased in lengths greater than 40 in.

In the course of a recent conversation with Mr. Speiden, of the Acheson Graphite Company, I learned that 45-in. electrodes will be made up on order, and that shortly the company expects to be able to furnish 60-in. lengths.

The availability of longer electrodes will certainly be appreciated by those who use this material.

Schenectady, N. Y.   C. A. Hansen.

Electrode Losses.

To the Editor of Electrochemical and Metallurgical Industry:

Sir.—My article in your last issue has been criticised on the ground that the formulas read in inches, centigrade degrees and calories instead of centimeters or Fahrenheit degrees and thermal units, and it has been claimed that this is inconsistent.

I do not agree with the latter. The reason I used inches was because that is the common unit of measurement in this country; and the reason I used the centigrade scale and calories was because most data in books and researches is given in these units, and most pyrometer scales read in centigrade degrees. I therefore used the units which I thought were in most general use in this country in connection with furnace work, and I still believe that the units I used are the most generally acceptable ones.

For the benefit of those who desire to use other units, however, I have calculated the formulas in terms of the other units. They are as follows:

When all the quantities are in terms of centimeters, gram calories and centigrade degrees, hence in absolute units (except the current), the constants in the original formulas (18) to (26) will be the same; that is, the formulas are equally applicable to either set of units, provided those units are used consistently throughout.

When T is in Fahrenheit degrees, and k is in terms of thermal units for 1 in. cube and 1° Fahr., that is, pound-Fahrenheit units commonly represented by b.t.u., and if L, S and r remain in inch units as originally specified, then the constant 4.186 in formula (18) becomes 1055.; the constant 2.894 in formulas (19), (20), (21) and (24) becomes 45.93; and the constant 0.3456 in formulas (22), (23), (25) and (26) becomes 0.02177.

Philadelphia, Pa.   Carl Hering.

Essentials of Professional Success in Mining and Metallurgy.*

By John Hays Hammond.

I am often asked what I regard as the essentials of professional success in mining.

First, and above all other considerations, I would place the possession of character.

An honest, clean cut, straightforward, conscientious young fellow, ambitious, persevering and last, but by no means least, level-headed, would, in my judgment, possess 75 per cent of the essentials of success; while in relative importance, I would not attach more than 25 per cent to the possession of a technical education. And I say this without in any degree depreciating the inestimable value of a technical education.

Without character, the professional monument of the engineer would be as unstable as an edifice where the mortar is deficient in lime. Therefore, I urge you to persevere in the development of character in its widest sense, and especially ever to be jealous of your reputation for integrity.

> Where ye feel your honor grip,
> Let that aye be your border.

In the mining profession the adage "Make haste slowly" applies with unusual force.

The tendency in recent years on the part of the mining engineer has been to neglect that practical experience so essential to the completion of its professional equipment. It is customary for the young engineer—after spending a few years in sampling mines, etc.—to enter the field as a "mining expert." The inevitable result is that he never acquires the practical knowledge that comes from years of experience in mines, mills and smelters, knowledge indispensable in his subsequent rôle of an expert in the determination of the value of mining properties.

There is to-day a scarcity of competent mining managers. The old, hard-headed practical mine manager who has worked up from the bottom round, step by step, and has acquired a thorough knowledge of all the phases of the mining business, from actual experience, has been superseded by the graduates of the mining schools, who, in many instances, after but little experience step into the management of a mining company.

And yet in spite of this scarcity, it is true that never before in the history of the mining industry are there to be found so highly competent mining managers as to-day, but these are the men who, after having received their technical training in the mining schools, have, like the old-time practical miner, acquired an intimate knowledge of the subject through years of experience in the subordinate positions of mining companies.

Formerly the report of a mining engineer or expert was confined to the geological and other cognate features of a mining enterprise; to-day, the engineer is expected not only to employ in his report information on these subjects, but to give his opinion as to whether the property offered for sale is worth the price asked for it. He is, indeed, an engineer of but limited usefulness if he does not go farther professionally than to present a purely technical report on subjects submitted for his consideration.

While the same responsibility obtains as formerly in the solution of the technical problems, the expert has often to deal with the financial and commercial aspects of the problem. Moreover, if he recommends the purchase of a property he incurs a certain moral responsibility for its efficient management, inasmuch as his professional reputation depends on the realization of his predictions as to the outcome of his clients' investment. For this reason the engineer sometimes passes from the rôle of an expert to that of a consulting engineer, bound to supervise both the technical and the business management of the properties purchased on his recommendation.

*Extracts from Mr. Hammond's commencement address, delivered to the Colorado School of Mines on May 28, 1909. The complete address is published in the *Quarterly* of the Colorado School of Mines, Vol. IV, No. 2 (August, 1909).

For many years I have strongly advocated the evolution of the engineer and expert into that of the "mining man."

There is now interposed between the mining engineer and the investors a class of men known as promoters. To what I regard as the butting in of these mine promoters I ascribe the failure of many mining enterprises. These promoters are, as a rule, men who have but a superficial knowledge of mining. Indeed, many of them have been failures in other walks of life and have gone into this vocation, because of the fact that it presents unusual opportunities of getting rich quickly. Not only are the majority of men in this class incompetent and ignorant about mining matters, but they are very often unscrupulous as well. But here, let me say, that I recognize the fact that there are among these mine promoters men who have a fairly good knowledge of practical mining and who possess undoubted integrity.

It is the promoter and not the honest miner who has brought discredit on the mining business.

As the result of an extensive and intimate experience with miners I can conscientiously say that with but few exceptions I have found them to be honest, certainly as honest as men of any other occupations.

It is hardly necessary to advise you, young men brought up in the West, to cultivate the friendship of the practical miner. I feel sure that a great part of what success I may have attained in my mining career has been due to the loyal friendship and assistance I have received from men of this class.

I should like to see the mining engineer acquire such a knowledge of business methods as to enable him to take the place of the mine promoter. This would prevent over-production, so to speak, on the part of the mining schools of the country, which are annually turning out hundreds of mining engineers. It would also insure that mining investments would be placed upon a more conservative basis, thereby greatly minimizing the risks of such investments.

To the engineer who in that way becomes the mining man to whom I have referred, an interesting and remunerative field for his professional activities would be opened.

I have noted of late, especially on the part of young mining experts, the exhibition of a sense of pride in having "turned down" a great number of mining propositions. I would recall in my own experience as a young engineer, a conversation I had with United States Senator George Hearst, of California. Senator Hearst was at that time by far the most important mining capitalist of the country. I had previously spent several months doing assaying work for him. At the time of which I speak he asked me "how I was getting along?" I replied with a feeling of ill-concealed satisfaction "that I had not as yet made any mistake in recommending worthless mining properties." Whereupon he said, "Well, my young friend, that is good as far as it goes, but have you made any recommendations that have turned out well?" In a crestfallen spirit I had to acknowledge that up to that time I had not; whereupon he said: "Then, I would advise you to go ahead and make a mistake or two and cover these mistakes up as quickly as possible by some brilliant success."

Now, I do not wish to encourage any zeal on your part to make mistakes, but I do wish you to base your claim for merit, not upon the negative virtue of not making a mistake by turning down properties, but upon the successful foundation of mining enterprises through your professional advice and direction.

Do not be from Missouri (no disparagement of that great State is intended) on every mining proposition presented to you. On the other hand, be not over-credulous and an easy mark. Remember that some of the greatest ore deposits being worked to-day were turned down on theoretical grounds by eminent mining geologists. Therefore, be open minded and ready, not unwilling to be convinced. In short, be from Colorado!

As the president of the American Institute of Mining Engi-

neers I delivered an address about a year ago on professional ethics. Some prominent members, however, have dissented from my views on the subject and have reproached me for wishing to inject into the sphere of the mining engineer what they regarded as too much commercialism. Nevertheless, I continue to regard mining as the aim to make a pecuniary profit in the exploitation of mineral deposits, and I do not believe (as I have said before) that the function of the engineer should be limited to the consideration of the academic features of mining problems.

In the address, I referred to the propriety of the engineer making a report for the vendor of the mining property. Such practice has been, I know, generally condemned. But a little reflection will show that the condemnation is not warranted, for it is neither wrong nor unreasonable that the owner of the mineral properties who desires to present such a statement of its nature and probable value as will insure the attention of contemplating purchasers, should, for the purpose, secure the assistance of one who knows how to make such a statement intelligently and in scientific language.

Such a report should, however, be plainly designated a "vendor's report," and the young engineer in making the report should use every precaution against the illegitimate or misleading use of its statements.

There arises also in this connection the question of the acceptance of contingent fees by the engineer. It seems to me that an expert of established and unimpeachable reputation is perfectly justified in recommending the purchase of a property and accepting compensation from the promoters, provided, first, and without qualification, that full publicity be given to the nature of his connection with the enterprise, and, secondly, that his compensation be contingent not upon the successful sale of the property, but upon the subsequent success of the undertaking.

The acceptance of commissions from the sales of machinery, etc., is another subject embraced in professional ethics. In many instances of a similar nature, affecting other professions, this practice seems to be established and condoned, if not avowedly justified, but in the mining profession I can see no justification whatsoever in the practice.

A young mining engineer should be as loyal to the corporation which he serves as to any individual. If he "cannot stand for" the policies or practices of his employer, it would be the straightforward course to seek employment elsewhere.

To retain the respect of his subordinates and thus assure the team work that wins in industrial undertakings, as well as on the athletic field, it is quite as important for the engineer in charge of operations as it is to inspire the confidence of his employers.

To be what is called a "good mixer" is an important qualification for the engineer. This is largely an hereditary trait, it is true, but the tendency to become exclusive and self-complacent can at least be overcome. Most valuable information as to mining developments and conditions in a new district can be acquired second-hand from even the unlettered stage driver of the district, and many an important hint is dropped, in a desultory conversation, in a smoking car.

These suggestions have not the dignity of a homily, but they are nevertheless of practical import.

There are two distinct classes of mining propositions with which the engineer has to deal in his professional capacity. The first is the so-called "gilt-edged" mining investments. Here the engineer exercises great conservatism, not only because there are relatively large sums of money involved, but also because investors in this class of mining are unfamiliar with the mining risks. The second is a class of propositions which, while speculative, are honest and legitimate undertakings. The development of mining prospects belongs to this category. Ventures of this kind should be confined to those who are willing and can afford to take greater risks in the hope of larger profits than accrue from the "gilt-edged" class of mining in-

vestments. If the engineer has already established the reputation of being successful in his mining ventures and has formed a clientele, for whom he has made money in these enterprises, he can then afford to take some chance in risking the money of his clients in this more hazardous class of mining propositions. Here I wish to impress upon you the necessity of exercising great discrimination in choosing the capitalists to be associated with you in these respective enterprises. As your experience expands in these matters you will appreciate the importance of this injunction.

In making reports the young engineer should present copious technical data, in case the report is to be submitted to other engineers, but when his report is to be submitted to the capitalist he should have in view chiefly the presentation of economic facts. Many of the reports of young engineers are altogether too voluminous to attract the serious consideration of a busy capitalist.

The last word of advice I have to give is to enjoin upon you the discharge of your civic duties. You should without the undue sacrifice of your professional opportunities, participate, to some extent at least, in the political movements affecting the localities in which you reside, and the welfare of the nation. For upon the welfare of our nation depends in a very large degree the prosperous conditions under which we can best succeed in our professional vocation.

Electric Zinc Smelting.

In our excellent French contemporary, *La Houille Blanche*, December, 1908 (Vol. VII, page 273), Mr. EUGÈNE FLEURVILLE publishes an interesting article on electric zinc smelting with special reference to a process of two French metallurgists, Messrs. E. F. CÔTE and P. PIERRON. The process is of special interest, as it is being carried out on a commercial scale.

General Considerations.

In the usual retort furnaces for zinc reduction only 10 per cent or 12 per cent of the calories set free by the combustion of coal are utilized. In closed electric furnaces operated at a temperature of at most 1800° C., it is possible to utilize 45 per cent or 50 per cent of the calories produced from electrical energy. Hence out of the 6,500,000 calories set free by the combustion of one ton of coal, only 700,000 are utilized in the retort furnace, while in the electric furnace the same thermic effect is obtained by an expenditure of 1,500,000 calories, which correspond to 95 or 100 electrical hp-days.

These figures are confirmed by experience. In the best Belgian and Silesian retort furnaces the amount of coal required per 1000 kg of zinc from 45 per cent to 50 per cent ores is in the average 2.5 tons, while according to tests of electric furnaces one ton of zinc can be extracted from the same ore by 2500 hp-days.

If the cost of coal in the retort furnaces shall be the same as the cost of energy in the electric furnaces, 95 electric hp-days or 100 hp-days must cost as much as a ton of coal, say, 12 francs or 13 francs ($2.40 to $2.60). The electric hp-year will then cost about 45 francs or 50 francs ($11.25 or $12.50). There are numerous enterprises in mountain districts where the cost is less. Electric zinc smelting is, therefore, in a more advantageous position than electric reduction of iron ore.

The cost of wages can be reduced by the electric furnace quite considerably without any doubt. The cost of maintenance of retort furnaces is due chiefly to the renewal of the retorts and may amount to 200 kg of clay retorts per ton of metal. Every zinc smelting plant has, therefore, its own retort factory. The corresponding expense with electric zinc smelting is the renewal of the electrodes, about 30 kg of carbon per ton of zinc; a large electric zinc smelting plant should, therefore, consider the erection of its own electrode factory. It is difficult to compare the cost in both cases, though it seems that the cost of maintenance of electric zinc smelting plants should be

less than that of retort furnaces. In any case, the first cost is less.

It is especially with respect to the reduction of zinc losses, however, that the electric furnace process can obtain a real superiority over present methods. In the Belgian and Silesian plants the loss of metal due to incomplete extraction and escape of metallic zinc vapors through the retort walls is only in exceptional cases below 10 per cent of the zinc contained in the ore, if blende containing from 45 per cent to 50 per cent is treated, and rises to 20 per cent if ore containing 25 per cent is treated. But, since most ores contain not more than 30 per cent, and since mechanical concentration to 50 per cent leaves 10 per cent to 15 per cent of the metal in the residues, it is seen that with present methods 20 per cent or 25 per cent of the metal contained in the ore is lost. On the other hand, with electric furnaces ores with an average content of 30 per cent can be directly treated with a total loss of less than 7 per cent, as is shown by experience on a commercial scale (see below).

However, the chief point to be taken into consideration is the well-known fact that zinc plants using retort furnaces must be located near a coal field or at least near a waterway by means of which coal may be brought cheaply to the zinc plant. The cost of the transport of zinc ore to the reduction plants puts certain localities to a great disadvantage. For instance, in the Pyrenees, in southern France, on the border of Spain, there are large deposits of zinc ore, but there is no coal available, and the transport of the zinc ore elsewhere would be very expensive. But since water-powers are available at the place, electric zinc smelting is the logical solution of this economic difficulty. It is then only necessary to ship the reduced metallic zinc instead of the zinc ore, and this saving in the expense of transportation is alone sufficient to encourage the electric furnace process in such localities.

Côte-Pierron Process.

The Côte-Pierron process is interesting with respect to its features of both reduction of the zinc ore and condensation of the zinc vapor. In order to facilitate the regulation of the temperature in the condenser independently of the furnace operation, these inventors have proposed to employ a column of granulated carbon compressed between two electrodes in a vertical cylinder with refractory walls. Part of the main current is shunted off and passes through the carbon, whereby the latter is heated. The temperature can be adjusted by varying the length of the column or the compression of the granulated carbon particles.

The chief difficulty in zinc condensation is due to the fact that the zinc is set free in a large amount of carbon monoxide. To avoid this disadvantage Côte and Pierron employ a process which is novel at least in its practical application, though it is known from chemical textbooks as a possible reaction. They let the zinc blende react with iron in the fused bath. The iron combines with the sulphur, and the zinc vapors are set free, according to the formula

$$ZnS + Fe = Zn + FeS.$$

This reaction takes place in the electric furnace quantitatively at a temperature relatively low for this apparatus.

This reaction has not been made use of probably because it was considered unsuitable for furnaces heated by coal.

Nevertheless, even this method does not yield pure zinc vapor. The ore even when apparently dry always contains traces of humidity, and its gangue contains more or less carbonates yielding carbonic acid when heated. Further, there is always a certain amount of air within the interstices of the charge when reduced to a granulated form. And this air enters with the ore into the furnace. But steam and carbonic acid gas and air when set free together with zinc vapor, even in small quantities, act energtically on the zinc vapor, which is easily oxidized. The result is the formation of "zinc mist." This is similar to the formation of mist in a cold and moist atmosphere.

The "zinc mist" causes less trouble for the condensation of zinc vapor than does carbon oxides gas, but if special means are not used to reduce it, it will result in the deposition of "zinc dust" in the condensers. This may clog the connecting tubes and form a serious difficulty in getting the zinc in form of liquid metal.

Messrs. Côte and Pierron, in a patent of 1904, avoid this inconvenience as follows: The iron and the zinc blende are fused separately in two crucibles under the action of electric arcs. From these two crucibles, the two fused metals pass into the reaction chamber, where they mix, the mixture being maintained fluid by resistance heating. Into this reaction chamber neither steam nor carbonic acid nor air can enter, since they have been before driven off in the fusion crucibles. From this chamber the zinc vapor enters the condenser.

This furnace has not been tried, however, in practice in this form, since its construction involved certain complications. It was the intention of the inventors to avoid any complications, as they were convinced that electric zinc furnaces, even more than other electric furnaces, must be primarily of greatest simplicity in construction.

Messrs. Côte and Pierron now treat the mixture of the blende and the iron in a single crucible, and then reduce the zinc mist by passing it through incandescent carbons which are interposed between the furnace and condenser. These carbons are kept at the incandescent point in a closed vessel from which air is excluded by means of two electrodes, supplied with shunt current from the main circuit.

The process is of special interest in connection with complex zinc-lead ores, as it permits a practically complete separation of the zinc from the lead. The lead is contained in the blende in the form of PbS. The crushed ore, mixed with comminuted iron particles and a suitable flux, is introduced into the electric furnace, in which it is heated first simply by the walls, which are kept red hot in a manner described later. The lead is precipitated during this first stage of the process and removed from the furnace.

Then the electric circuit is closed and the charge is heated by means of the current. The iron displaces the zinc, which is set free in form of vapor, and is condensed in the condenser, practically free from lead. The iron sulphide collects on the bottom of the furnace in form of a liquid bath, covered by a fused slag. By increasing the heating effect the slag is rendered liquid, and most of the zinc that is contained in it is set free. At the end of this second step of the treatment, the iron sulphide and the slag are tapped from the furnace. A new charge is introduced and the operation begins again.

The form of furnace which is the result of numerous tests of Messrs. Côte and Pierron, to realize the foregoing method in practice, is shown in Fig. 1 in vertical and horizontal sections. A is the crucible, the bottom of which contains in its center a projection b. The crucible consists in its lower part and side walls of graphite encased by sheet metal and is connected to one pole of the electric circuit. The other pole is connected to the vertical electrode C, the lower end of which is above the projection b. The roof is formed by the arch D of refractory brick. The charge is introduced through the holes e, which are closed during operation by means of refractory stoppers; f is the tapping hole.

The zinc vapors leave through g and pass through a long channel h to the condenser I, which is formed of a chamber with vertical refractory walls, filled with carbon particles which are kept hot at a temperature of red cherry. The condenser is tapped through the hole l. Air can be admitted at the top through j, while k is a stack, so that it is possible to bring the carbon in the upper part of the condenser to red heat. The downward passage of the carbon is regulated in such a way that the carbon is maintained in the uppermost part of the chamber I at a temperature sufficient for the reduction of the "zinc mist" and the condensation of the zinc. The opening m is provided for cleaning the channels g and h in case of clogging. The described method of heating the con-

denser is simpler than by means of an auxiliary electrode. Nevertheless, there would be no difficulty in heating the carbons in *l* electrically. The principle of the apparatus remains the same.

The charge to be treated is placed on the top of the furnace *D*, where it is dried in advance of being introduced into the furnace. When the furnace is tapped, the electrode *C* is lowered and brought into contact with the projection *b*. The feeding hole *e* is then opened and the new charge is rapidly pushed into the furnace, whereupon the feeding hole *e* is again closed and a new charge is placed on top of the furnace for drying.

The electrode *C* now remains in contact with the projection *b*, so that practically all the current passes through *C* and *b* and none through the charge. The charge is, therefore, heated

Fig. 1.

Fig. 2.

FIGS. 1 AND 2.—SECTIONS OF ELECTRIC ZINC FURNACE AND CONDENSER.

simply by contact from the hot electrode *C* and the projection *b*. The lead precipitates and leaves the furnace through the tapping hole *f*, which remains open.

During this time the door *l* of the condenser is also left open, and the pieces of carbon are allowed to slide down in the condenser *l*, so that they clean the condenser thoroughly, while the temperature reaches the upper limit of the range within which zinc is condensed. The vapors set free from the fused bath—iron, silica and lime—pass through *h* to the condenser and are arrested by the carbon pieces in the lower part of *h*. They are automatically removed from the condenser whenever the door *l* is opened to tap the molten zinc and let the carbons pass down. It is, therefore, easy to remove any momentary clogging that may occur. This is of great importance.

When it is thought that all the lead which can be removed by

precipitation has gone out of the furnace through the tapping hole *f*, this tapping hole *f* and the condenser door *l* are closed and the electrode *C* is now gradually raised so as to heat the charge by resistance and arc heating. Iron sulphide now forms and collects on the bottom of the furnace. But the current does not pass through it, since the current passes essentially through the electrode *C* and the projection *b* and the charge between their two ends. Finally, by simple arc heating, the zinc is set free and the slag is brought into a fluid condition convenient for tapping. At this moment the layer of slag between the electrode *C* and the projection *b* receives practically alone the whole thermic effect of the current. As a result the volatilization of the iron is reduced, the crucible is better preserved, and the electro-thermic efficiency is raised.

After all the zinc has been set free, the furnace is tapped and a new run begins.

Zinc vapor has a tension which increases very rapidly with the temperature, while its specific heat is low. When the zinc vapor leaves the crucible it is at the temperature of 1200° C. or 1300° C. It is, therefore, necessary to bring it into contact with as large a surface of condensation as possible. If this precaution is not taken the zinc vapor will pass along too rapidly while it is at a high temperature. A condensation in form of zinc powder will be the result. In order to get the right conditions of condensation surface, volume and temperature, the cylindrical condenser is filled with pieces of carbon practically at red heat. The zinc vapor rises upward within this column of carbon.

In the moment when it passes from the channel *h* into the condenser *l*, the vapor is still very hot and serves to bring the carbon particles up to the temperature of the reduction of zinc oxide contained in the vapor. While rising upward in the condenser cylinder *l* the vapor cools off by giving its heat to the carbon pieces, which, on the other hand, are sufficiently hot to prevent too rapid a cooling of the vapor. On contact with the carbon surfaces the condensation of the zinc takes place gradually. The little drops of zinc which are formed trickle down on the carbons and form thereby new condensing surfaces of great activity so as to condense more zinc vapor, which is rising upward.

The liquid zinc collects on the bottom behind the door *l*, through which it is withdrawn from time to time.

The carbon monoxide resulting from the reduction of the zinc mist escapes through the stack *k* with the gases of combustion of the pieces of carbon from the upper part of the condenser. Whenever fumes of zinc oxide are seen to pass out of the smokestack it is a sure indication of poor condensation and the conditions must quickly be adjusted, either by regulating the current in the crucible or the speed of combustion or the passage of the carbons down in the condenser.

This regulation of the conditions in order to obtain good condensation requires skilled and attentive workmen just as is the case with retort furnaces. But the electric furnace is a great deal more easily attended to and any correction of the conditions can be done much more quickly and with much less trouble and with less loss.

It might be objected that the use of iron as reducing agent is uneconomical compared with the ordinary process of zinc blende roasting and reduction. But the inventors do not think so. Nine hundred kilograms of iron are required per ton of zinc (1000 kg) to be extracted. The iron sulphide produced contains 36 per cent of sulphur, while the zinc ore, even if concentrated to 50 per cent, contains only 17 per cent. The desulphurization of the iron sulphide withdrawn from the furnaces is believed to be much more advantageous than that of the zinc ore. It can be carried out cheaply by simple methods, and the impure iron thus obtained can be used again in the zinc furnaces.

If it is not desired to regenerate the iron it is used in form of turnings or drillings. The sale of the iron sulphide covers part of the expense of buying the turnings.

Electric Zinc Smelting on a Commercial Scale.

The first experiments with the above process, outside of the laboratory of Messrs. Côte and Pierron, were made in 1906, at Lyon, with a 100-hp furnace. The gas company of the city of Lyon had placed at their disposal for certain hours during the day a direct-current generator giving 1200 amp at 250 volts. This was used in connection with a water rheostat by means of which the voltage could be reduced to 25 volts, which was the difference of potential of the electrodes.

The furnace consisted of a cylindrical crucible of 40 cm inside diameter and 45 cm height, carefully built up of magnesia brick and held together by a metallic casing of 1 m diameter and 110 cm height. On the top of the furnace a hopper was provided for introducing the charge. The electrodes were placed vertically along the central axle of crucible and hopper.

The stationary lower electrode consisted of a carbon cylinder of 20 cm diameter, passing through the bottom of the crucible and projecting 10 cm into the interior. The smaller movable upper electrode was suspended into the furnace through the opening through which the hopper was in connection with the crucible. A conical valve, movable along this electrode and resting on the inner walls of the hopper, closed the furnace. For introducing a new charge this valve was raised. The arrangement was satisfactory in preventing any zinc vapors from leaving the furnace through the hopper.

Two tapping holes were provided, one directly at the bottom and the other 15 cm higher. From the top of the furnace a channel conducted the metallic vapors to the condenser. The compartments provided at the end of this channel to receive the zinc had various forms and dimensions; several of them could be heated externally.

The work with this furnace was not undertaken to solve at once the problem of condensation of the zinc in liquid form, but rather to study some fundamental chemical problems of the process, especially the displacement of the zinc by the iron, the power consumption, the losses of metal, the consumption of the electrodes, and the wear and tear of the crucible, etc.

In these first experiments the composition of the ore, the composition of the gangue, the additions of iron and of flux were systematically varied. The results of one of the last experiments of this series of tests are given as follows:

With an ore containing 46 per cent of zinc, with a silica gangue and a content of not more than 4 per cent of limestone, the charge being reduced to particles of a size from 5 mm to 10 mm, it was possible to smelt per hour a charge of 30 kg of zinc ore plus 13 kg of iron plus 5 kg of lime (the total weight being, therefore, 48 kg). The charging was done every quarter of an hour, 12 kg being charged every time. The furnace was tapped every hour, the bath being very fluid.

The current varied between 1100 amp and 1200 amp at a voltage ranging from 30 volts (during a few minutes after introduction of a new charge) to 65 or 70 volts on the regular operation. The energy consumption was 68 kw-hours.

The quantity of zinc retained in the slag was in the maximum 3 per cent of the weight of metal contained in the ore. The weight of zinc powder and condensed zinc obtained per hour was 13.7 kg. This is quite a satisfactory result for such a small furnace in comparison with the output of retort furnaces.

After 36 hours of running the loss of the movable electrode was 7 kg. The wear and tear of the magnesia brick was also satisfactory. After these preliminary experiments the Société des Fonderies Electriques was formed in May, 1907, to exploit the Côte and Pierron furnace on a larger scale.

The program was not to solve all problems at once, but to proceed in two successive steps. The first step included the study of types of furnaces most appropriate for the purpose and the establishment of the cost of operation and possible profits during one year of running a plant of about 500 hp. During this first operation no attempt was made to condense the zinc, the purpose being to produce directly zinc oxide or white zinc in commercial form from low-grade ores. After this first investigation has been successfully concluded, the second step will be to build a plant of 1200 hp to 1500 hp making white zinc. With the different furnaces of this plant in operation it will then be convenient to learn the tricks of handling large volumes of zinc vapors. And with the furnaces in industrial operation the production of condensed liquid zinc is to be gradually increased until the problem of obtaining practically all the zinc in ingots is finally solved. Even now, without special experience, a portion of condensed metal is obtained.

The Société des Fonderies Electriques has successfully gone through the first step of their program outlined above. They rented, in the May of 1907, an old carbide plant which had been abandoned in the Pyrenees at Arugy on the railroad from Pau to Laruns-Eaux-Bonnes in an important mining district which furnishes the zinc blende. These works contain a small water-power plant, with two alternators each of 250 hp, from which alternating current with a frequency of 50 is transmitted at 3000 volts over a line of 900 m length to industrial establishments in the neighborhood.

Several zinc furnaces have been installed in these buildings. In view of the special conditions in this plant it was necessary to modify as little as possible the arrangements, and the furnaces had to be placed at quite a distance from the transformers which lower the voltage from 3000 to the voltage required at the terminals of the furnace. In spite of all precautions taken the power factor of the installation was well below unity.

The transformers can be connected in several ways so as to give either 135 volts or 90 volts or 45 volts. Hardly at any time more than 300 hp is available at the electrodes and very often the furnaces have to be operated alternately. Messrs. Côte and Pierron have first tried various types of furnaces with currents from 3000 amp to 6000 amp and at 90 volts or 45 volts or even 40 volts. They have tried rectangular furnaces with two electrodes in series above the fused bath and other furnaces, also with two electrodes above the bath, but these two connected in parallel, while graphite blocks embedded in the bottom of the furnaces form the other pole. After numerous experiments extending over more than six months they have come back to the cylindrical furnace with one electrode and the graphite crucible forming the other pole. The arched roof is built of fire brick and lined with magnesia brick.

With these furnaces various systems of charging have been tried and the place of the hopper, the speed and regularity of charging have been varied. The advantages and disadvantages of the different systems have been compared with that illustrated in Fig. 1; the latter has finally been adopted.

Whatever the position of the hole through which the zinc vapors leave the furnaces, they get first into the combustion apparatus in which the vapors are changed to oxide fumes, which are then conducted through metallic tubes into large chambers for collection.

Numerous tests have been made on the possibility of devising better forms of the combustion apparatus, on the quantity of ore to be introduced, on the temperature most suitable for a good oxidation, on the best speed of passage of the fumes through the chambers and filters. The author thinks that the manufacture of zinc oxide involves its own problems, and he is not sure whether these problems are easier or more difficult than the problems of zinc condensation.

The following are the results of the run of a furnace with a single electrode in a graphite crucible:

Total time of series of experiments, 240 hours.
Weight of ore smelted during that time, 14,560 kg.
Average content, 43.6 per cent.
Weight of iron mixed with the ore, 6235 kg.
Weight of fluxes added to the charge, 3480 kg.
Mean current, 4300 amp; voltage, 40; power factor, 0.80.
Weight of zinc oxide obtained, 6730 kg.
Metallic zinc condensed before passage to the combustion apparatus, 182 kg.

Zinc content in the slag and iron sulphide, 2.7 per cent.
Consumption of electrodes, 193 kg.
Electric energy cost 65 francs ($13) per hp-year.

The electrodes are not made by the company itself, as the consumption is not large enough. They cost 52 francs ($10.40) per 100 kg. Of these 18 francs ($3.40) are expenses for transporting the 100 kg to the works. The iron is delivered at the plant at 60 francs ($12) per ton and the lime at 15 francs ($3) per 1000 kg. The workingmen get 3 francs (60 cents) in the average per day. Under these conditions the cost of the 6912 kg of oxide and metallic zinc of the above run was 2396 francs (not including general expenses, but including maintenance of the furnaces). The cost of packing and loading the cars is to be added. This brings the total cost up to 2631 francs.
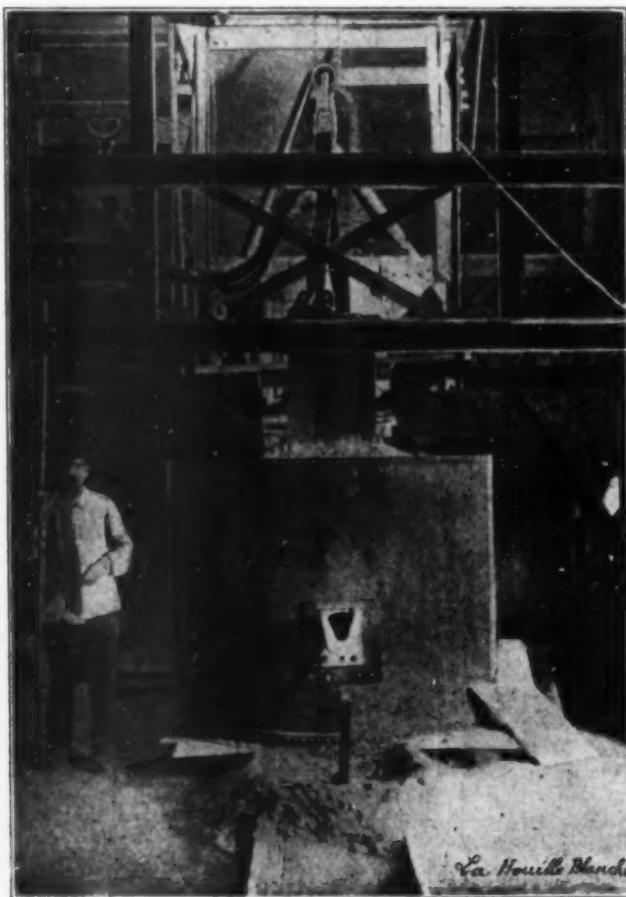

FIG. 3.—VIEW OF ELECTRIC ZINC FURNACE.

The oxide was sold at 46.30 francs per 100 kg, which gives a total income of 3200 francs.

The treatment of zinc blende with iron has, however, been abandoned for the production of commercial zinc white because a small percentage of iron would volatilize and mix with the zinc oxide fumes (1 or 2 per cent, according to the conditions of operation). The presence of this iron in the zinc white is objectionable for certain applications. The zinc condensed to the metallic state, however, contains very much less iron.

In order to obtain directly from crude low-grade ore an absolutely white zinc white of practically the same purity as other commercial zinc white, the inventors have had recourse to another reaction, namely, that of lime and carbon on fused blende. This is given by the equation

$$ZnS + CaO + C = CO + CaS + Zn.$$

In this case the presence of the carbon monoxide is no cause of trouble, since the object is not to condense the metal. It is noteworthy that in the course of tests made with this method there are never found any traces of condensed metal at those places where it is always found when the reaction with iron is carried out.

For eight months one of the furnaces at Arudy has produced zinc white according to the lime-carbon process. The sale of this zinc white has permitted the recovery of a large part of the expenses of the experiments.

One of the furnaces used in these tests is shown in Fig. 3. It is formed by a graphite crucible of 110 cm inside diameter and 65 cm height, covered by an arched roof of magnesia brick and held together by a sheet-iron casing, 195 cm in diameter, which is connected to one of the poles of the electric circuit. The electrode had a cross-section of 1000 sq. cm. The cost of the furnace ready to begin operation, with all mechanical and electrical accessories, was 4850 francs ($970).

The charge requires less than two minutes, the tapping three or four minutes at the most. Two men can easily attend to two furnaces of much larger capacity. When the operation is once regulated to suit the treatment of an ore of given composition—which can be done in less than 24 hours—the furnaces operate without any other attendance except the purely mechanical operations of charging and tapping, which are to be carried out by the workingmen at regular intervals.

The working men during this test were unskilled men and had never seen anything of a metallurgical furnace. Their wages varied from 2.75 to 3.25 francs (55 to 60 cents) per day. This shows that the electric furnace is more easily attended than retort furnaces.

The following figures refer to a series of tests in which 76 tons of ore were smelted with a consumption of energy quite similar to those quoted above:

In 600 hours, or 25 days, 28,345 kg of zinc blende, with an almost pure silica gangue containing 2 to 4 per cent of iron, 1 per cent of other metals and analyzing on the average 37.28 per cent of zinc were smelted. The current was 3800 amp at 42 volts, with a power factor of 0.85; 12,384 kg of lime (both for reaction and flux) were used and 3146 kg of carbon. The ore charged into the furnace contained 10,587 kg of zinc, from which theoretically 13,193 kg of oxide should be obtained. The recovery was, in fact, 12,370 kg.

The content of zinc in the slag and calcium sulphide varied during these tests from 1.2 to 1.8 per cent.

The consumption of electrodes was 1286 kg, but this includes 637 kg of electrode ends which were not consumed, and with a better designed plant this amount could be reduced to a certain extent.

Of course, a larger electric zinc smelting works, would erect its own electrode factory and hereby reduce considerably the expense of this item.

The lining of the furnace had to be replaced after two months.

The cost of coke at the works was 39 francs ($7.80) per ton.
The total cost of making these 12,370 kg of oxide was 4598 francs, and they were sold for 6102 francs.

The zinc oxide produced is classed in two brands, according to its whiteness. The larger part, about 70 per cent, constitutes the better quality, while 3 or 4 per cent, constituting the parts recovered in the flues, are returned into the furnace with a new charge.

The two qualities are nearly of the same degree of purity. They analyze 98.6 to 99 per cent of zinc oxide, 0.4 per cent of moisture, 0.2 or 0.3 per cent of iron and 0.5 to 0.7 per cent of silica, lime, and other metals, the latter being present only in traces, since the ore itself is almost free of them. Some 300 barrels, each of 100 kg, have been sold at Marseilles, Paris, and Lyon in competition with German and American zinc white made by other methods.

The author finally remarks that the figures of the tests given above are perhaps less alluring than those given by other experimenters, but the above figures represent true figures from operation on a large scale, and are not estimates based on laboratory experiments.

Electrode Efficiency of Furnaces.

By Carl Hering.

If the voltage between the inside or hot ends of the two electrodes of a furnace be divided by that between the outside or cold ends, a figure is obtained for which the writer has suggested the name electrode efficiency, as it is a true measure of the efficiency of the furnace as far as the loss of power in the electrodes is concerned; for if this figure were 100 per cent, it would mean theoretically ideal electrodes in which there is no loss, while if it is 75 per cent it means that a quarter of the whole energy is lost in the electrodes. Such a figure, therefore, is a measure of the degree of perfection of the function of the electrodes as a means for efficiently conveying the energy into the furnace, apart from all other losses or efficiencies.

In an article on "The Laws of Electrode Losses in Electric Furnaces," published in the preceding number of this journal, p. 442, the writer referred to this electrode efficiency and the interesting constant electrode voltage on which it depends, but owing probably to the brevity of this reference it appears that it was not correctly understood, judging from an editorial remark concerning it. The object of the present article is to endeavor to describe this more clearly, as it has an important bearing on the design of furnaces.

The essential element in this electrode efficiency is, of course, the drop of voltage between the hot and cold ends of an electrode. It was shown in that article that for any given electrode material there exists a curious and interesting minimum drop in voltage below which it is not possible to go without again increasing the total loss. An electrode is, therefore, different from an ordinary conductor of electricity, for with the latter the loss in it can be reduced to any degree to which one desires to go by merely increasing its section and diminishing its length.

The reason for this difference is that there is another loss through an electrode; namely, the heat conducted off by it from the interior of the furnace, which, as it costs quite as much per watt as the loss due to its electrical resistance, is of equal importance, and it is this loss which increases by increasing the section of the electrode or reducing its length. And it is when both of these losses are taken into consideration that it was found that there was a minimum drop of voltage in electrodes below which the total losses again increase.

This voltage the writer suggested naming the "electrode voltage," as he found it to be a characteristic physical property of the material, like density, conductivity, etc., and is of use in designing electrodes, of more importance even than the electrical and the thermal conductivities alone; it depends on both of these combined. Neither of the two conductivities alone is a criterion of the suitability of a material for an efficient electrode, as was pointed out in that article, but the electrode voltage is a true measure of this latter quality; the lower this electrode voltage of a material the higher will be the electrode efficiency.

The features of this electrode voltage may be summarized briefly as follows, under the assumed conditions stated in that article:

It is the lowest drop in voltage to which it is possible to go without again increasing the total electrode loss. It has a different value for different materials, but is a constant for each material. It is, therefore, a physical property of the material—that is, it is independent of the length or cross-section of the electrode, or the current passing through it, and, therefore, no changes in these can further reduce it. It is, however, dependent on the temperature drop in the electrode and hence as a constant it must be understood to be for 1 deg. of temperature drop. It increases as the square root of the temperature drops. It bears a fixed relation to the electrical and thermal conductivities combined, and, in fact, is determined by them. It varies as the square root of the quotient of the heat conductivity divided by the electrical conductivity. For 1 deg. temperature drop it is therefore equal to, in volts,

$$e = A \sqrt{\frac{k}{K}} \qquad (1)$$

in which k is the thermal conductivity, K the electrical conductivity and A a constant depending on the units used. For any given temperature drop this value must be multiplied by the square root of that drop. As the electric resistivity r is more commonly used than the conductivity, this formula is more convenient in the form

$$e = A \sqrt{rk} \qquad (2)$$

When r and k are given in terms of cubic centimeters, ohms and gram calories per second, and when the unit of temperature is 1° C., then the constant A will be 2.894 when e is in volts. It will be the same when r and k are given in cubic inch-units instead of centimeters. When the units are cubic inches, ohms, thermal units (b.t.u.) and Fahrenheit degrees, the constant A is equal to 45.93. These values of A are mere mathematical constants and involve no physical properties.

As an illustration of the approximate value which e has for graphite, for instance, assume that $r = 0.000266$ and $k = 0.24$ in cubic inch, ohm, gram calorie, centigrade units, then

$$e = 2.894 \sqrt{0.000266 \times 0.24} = 0.0231 \text{ volt.} \qquad (3)$$

That is, for 1° C. drop in temperature and perfect conditions, the least drop of potential in any graphite electrode will be 0.0231 volt, no matter what its size, or what the normal current is; reducing the voltage still more would increase the loss again. It also means that at this voltage only will the hot end of the electrode be raised to the furnace temperature by the C^2R heat, which was shown in the article mentioned above to be the proper condition under which electrodes should be operated to give the best economy of power, for under those conditions only will no furnace heat be lost through the electrode.

Suppose the temperature drop in the electrode is 1600° C.; the square root of this is 40, hence the voltage drop for this temperature range will be $40 \times 0.0231 = 0.92$ volt for any correctly proportioned graphite electrode, no matter what its size nor what the normal current. Hence a 50-volt furnace with graphite electrodes has an electrode efficiency of 96.3 per cent no matter what its size, provided only that it is correctly designed. It is of interest to note that this minimum electrode loss is quite small.

Returning now to the electrode efficiency, it will be seen from the above that as the drop of voltage in the electrode is a constant depending only on the material and the temperature (assuming the electrode to be correctly designed) the designer has no choice left concerning this important factor in the electrode efficiency when the electrode material and the temperature are given; he must take it as it is determined for him by nature—that is, by the physical constants of the material.

The only choice he may have concerning this voltage drop is in the temperature and the electrode material. Ordinarily the temperature is fixed by specification, thus leaving no choice there; the only thing the designer can do is not to exceed this unnecessarily, for instance, by not using an arc if a resistor will answer, as arc temperatures are usually volatilization points. Other and more important considerations than a small gain in efficiency will, however, generally decide this.

The other choice lies in the material. As long as this is limited to graphite and carbon the choice is easily made when the two conductivities of each of these materials are known. But here again a small gain in efficiency should not be allowed to outweigh other and perhaps much more important advantages of one over the other. According to the best figures available at present (which may be only very rough approximations) the electrode voltage of graphite for 1° C. is 0.0231 volt and for carbon 0.0224; the difference is only a few per cent, and therefore of little consequence.

In many transformation devices the usual way of increasing the efficiency is by reducing the internal losses, but from what has been shown above an electric furnace with electrodes differs

from these, at least in the electrode efficiency, in that the electrode loss is fixed by the material and temperature, thus leaving no choice to the designer. All he can do is to reach this minimum loss; he cannot go below it.

Hence, the only way left in which the electrode efficiency can be increased by the designer is by increasing the total voltage of which this drop in the electrode is a fractional part; or, in other words, to produce the required watts in the furnace with as high a voltage and as low a current as possible. The lower current will not reduce the drop in the electrode, as was shown above, if the electrodes are correctly designed, as it will merely reduce the relation of the cross-section of the electrode to its length. The increased efficiency is due only to the higher voltage.

It seems, therefore, that it cannot be said that the minimum electrode loss is or is not identical with the maximum furnace efficiency if the latter refers to the electrode loss only, because there is no theoretical maximum furnace efficiency, as the furnace voltage may theoretically be increased indefinitely. If the total furnace voltage is fixed, the electrode efficiency is fixed thereby, because the drop in the electrode is a constant. No complicated formulas are required for this; in fact, the formula for the electrode efficiency in per cent is simply

$$\frac{E - 2c}{E} \tag{4}$$

in which E is the total voltage of the furnace and c the constant drop in each electrode.

There are, of course, numerous practical considerations which may make it impracticable to adopt the theoretically perfect design; but this does not concern the present discussion, which is intended to show what the ultimate conditions are which should be reached if practicable and beyond which it is not possible to go.

PHILADELPHIA, PA.

A New Refractory Material.

By Prof. Jos. W. Richards.

"Moler" is the local name for a foliated diatomaceous deposit found in the argillaceous eocene deposits in Jutland, northern Denmark, particularly in Mors, Fur and at Silstrup and Ertbolle on the Lim Fjord. Up until recently no use has been found for this material.

Mr. G. A. Heyermann, director of the Royal Polytechnic Institute of Copenhagen tried to use it in the mixture for sand-lime bricks, but found it unadapted to this use. The Clay Laboratory of the Danish States Testing Laboratory has, however, been successful in producing bricks from mixtures of clay and moler in various proportions, and from moler alone, with very interesting results, particularly as concerns the properties of these bricks.

In the first tests, moler was mixed with 25, 50 and 75 per cent of marl, and with 25 and 50 per cent of red clay; afterwards bricks were burnt from moler alone. Contrary to ex-

pectations, moler alone burnt to a fine red brick, very firm and light, and of such toughness that a nail could be driven through without cracking it. The specific gravity of these bricks was about 1, and their strength about that of common bricks.

These results were so encouraging that the "Skrikes Institution" made a grant of 1000 kroner to investigate the possibility of founding thereupon a new industry. The chief engineer of

FIG. 2.—MOLER BRICK FURNACE.

the Clay Laboratory, Mr. Fischer-Moeller, inspected the moler deposits in company with Captain Loof, of Hobro, and Dr. V. Madsen, State Geologist, and succeeded in finding a fine bed of the material at Ejersley, provice of Mors.

This is exposed as a cliff 16 m to 20 m high, the white moler being in corrugated strata interspersed with dark stripes of volcanic ash (Fig. 1). The moler was separated from the volcanic ash, and Captain Loof burnt a quantity of it into bricks in his brick-kilns at Vindo, near Hobro.

Various methods of molding, drying and burning were tried, and bricks produced with specific gravity of 0.87 to 1.13 (hardest burnt), and crushing strength 86 to 230 kg per square centimeter (1230 lb. to 3290 lb. per square inch). In all cases their power of absorbing water was considerable, up to 50 per cent of their weight. Their particular properties are their great strength in proportion to their lightness and the heat insulating quality. They are suitable for partitions, floor constructions, arches of every form. They are not suitable for outside use, because of their porosity and absorption of water.

FIG. I.—CLIFF OF MOLER DEPOSITS.

As a refractory they are, however, a most promising material. Their porosity makes their heat conductivity unusually low, and it remained only to test their behavior under strong heat. In the Eastern Gas Works, Mr. Irminger constructed the arches above the retorts of them; at the poor house, Sundholm

Copenhagen, the chief engineer used them for the masonry of steam boilers. In both cases they resisted the heat satisfactorily.

The Frederiksholm Brick & Limeworks Company, Ltd., had the Clay Laboratory conduct some careful experiments to determine their refractoriness. For this purpose, a small vertical shaft (Figs. 2, 3 and 4) was constructed 1.5 m (5 ft.) high,
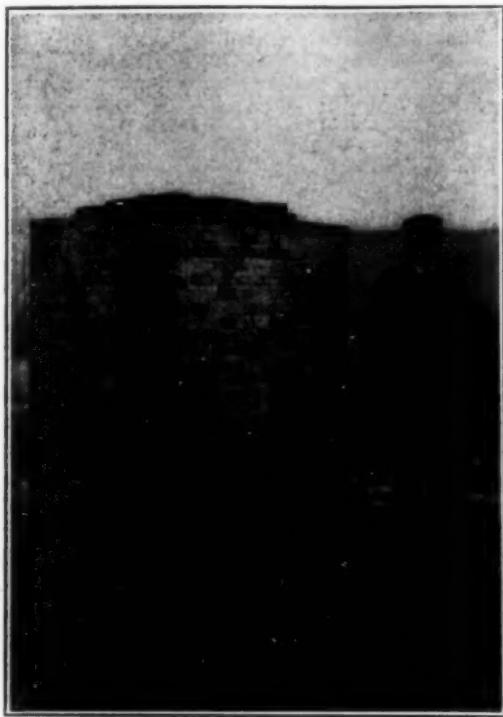
FIG. 3.—MOLER BRICK FURNACE.

1 m square, and with walls one brick (6 in.) thick. The interior was heated by six large gas burners, burning 1200 cu. ft. of gas per hour. The temperatures were measured by Le Chatelier thermo-electric couples placed in iron tubes built into the walls. Temperatures up to 1100° C. were thus recorded; parts of the walls were undoubtedly hotter than this. The results of this test were to prove the complete durability of the moler bricks at these temperatures, the faces exposed to the greatest heat were somewhat vitrified.

Tests at higher temperatures are lacking, as are also exact data on the heat insulating properties, but it is definitely stated that the heat conductivity is phenomenally low.

Assuming the reliability of these statements, we have here a most excellent refractory material for intermediate use, as a heat insulator, in the walls of furnaces, as courses between the refractory lining brick and the ordinary outside brick. The low heat conductivity should reduce greatly the heat losses through such composite walls. Its use for electric furnaces, outside of the carbon or magnesite lining, and inside the iron shell, should be highly advantageous.

The manufacture of these bricks is now in the hands of the Fredericksholm Brickworks, Copenhagen, Denmark, from whom they may be obtained commercially. The Fredricksberg Tramway Company, at their new electric power station at Finsensvej, have used 40,000 of them in setting their boilers, also, because of their heat insulating properties, for the masonry of "economizers," and, because of their lightness, for lining a large high horizontal flue.

The above data are taken from a recent report of the Danish State Testing Laboratory, which, under the title "On the Development of Testing of Materials in the North," was presented to the members of the Fifth International Congress for Testing Materials, recently held in Copenhagen.

Metal Statistics.

We have received, through the courtesy of the Metallurgical Company of America, the fifteenth annual issue of the "Comparative Statistics of Lead, Copper, Spelter, Tin, Aluminum, Nickel, Quicksilver and Silver," compiled by the Metallgesellschaft, the Metallurgische Gesellschaft A. G., and the Berg-und Metallbank, A. G. (Frankfort-on-Main, July, 1909).

The world's production of lead, copper, spelter and tin, in metric tons, during the last three years is given as follows:

	1906	1907	1908
		in metric tons	
Lead	973,100	984,300	1,052,500
Copper	717,800	703,000	738,900
Spelter	702,000	738,400	722,100
Tin	98,800	97,700	106,500

The average yearly increase in production for the last 10 years was 2.7 per cent for lead, 4.5 per cent for copper, 4.0 per cent for spelter, and 3.9 per cent for tin.

The consumption in metric tons in 1908 in the four principal countries was as follows:

	U. S.	Germany	Great Britain	France
Lead	321,000	211,300	228,800	103,000
Copper	210,600	180,700	128,900	73,900
Spelter	188,300	180,200	138,500	78,000
Tin	32,800	16,700	19,900	7,600

The average yearly prices for all these metals have reached in 1908 a level below that of the average for the last ten years, though it must be borne in mind that the latter average includes the boom prices of 1906 and 1907. Including the year 1908 we have the results here given:

	Average price for ten years			Average price for twenty years		
Lead	£14	5	11	£12	12	
Copper	68	16	4½	58	4	3
Spelter	22		5½	20	9	10
Tin	137	17	10	108		2

The influence of prices in 1908 upon the earnings of purely

FIG. 4.—MOLER BRICK.

mining and combined mining and smelting enterprises is very evident, the falling off in the profits of these concerns having been in almost all cases serious. The purely smelting concerns also, whose business year does not coincide with the calendar year, and which therefore were still to some extent affected by the violent fluctuations of the year 1907, suffered to a considerable extent. In this connection, there was another

factor which was particularly prejudicial, viz: the fact that in the past year also prices of fuel and raw materials in many countries had not yet properly adjusted themselves to the altered economic conditions.

Then follow detailed notes on lead, copper, spelter, and tin and—as a new feature of these statistics—a statement of the share capital of important metal-producing stock companies, together with their highest and lowest share quotations for the last three years.

The main part of the book is taken up as usual by comparative statistical tables on production, consumption, and prices of aluminum, lead, copper, nickel, mercury, silver, zinc, and tin. It is, of course, impossible to abstract these tables. It is unnecessary to emphasize the long established thoroughness and reliability of these well-known yearly statistics.

Observations Upon the Alloys of Iron and Manganese.

By Chas. F. Burgess and James Aston.

With the development of modern steel-making processes manganese may be said to be present in practically all steels. As the universal cure-all, the tonic of the metallurgist, it is added as a deoxidizer and in sufficient excess (up to about 1 per cent) to minimize the effect of the sulphur present. In larger quantities, running to a percentage of 10 or upward, we find it in various alloy steels for the special properties conferred.

As far as the resulting mechanical properties are concerned, we are justified in using considerable amounts of manganese, since the effect is beneficial, rather than otherwise. But how about its use in the large quantities of steel employed for its purely electrical features, in the form of sheet and also as castings?

In connection with our work upon the properties of electro-
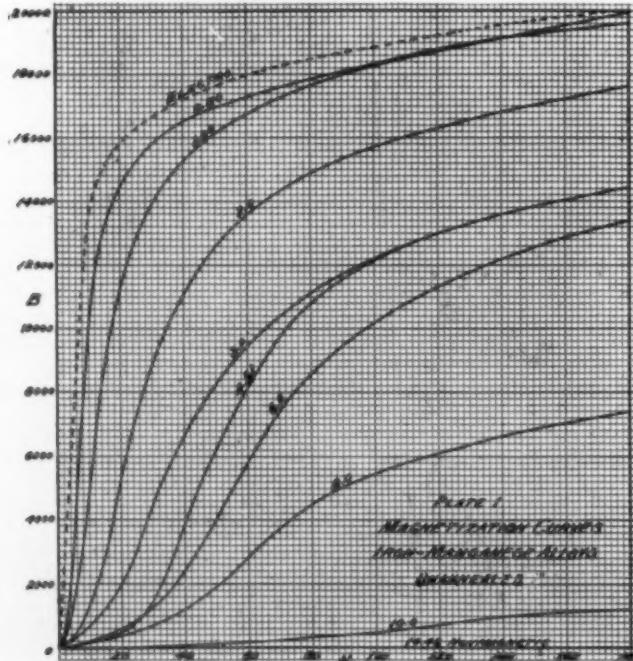
FIG. 1.—MAGNETIZATION CURVES, IRON-MANGANESE, UNANNEALED.

lytic iron and its alloys, carried out under a grant of the Carnegie Institution, of Washington, we have observed certain peculiarities in the magnetic behavior of the iron-manganese alloys which may be of interest. The primary constituent in the preparation of these alloys is iron of high purity, gotten by double electrodeposition from Swedish iron anode bars. The character of this material may be seen in the following table:

	Swedish Anode	Double refined as deposited	Electrolytic fused and forged
C	0.260	0.012	0.047
S	0.007	None	0.005
Si	0.109	0.013	0.062
P	0.007	0.004	0.016
Mn	0.021	None	None
Iron (by difference 99.971)			

In view of the very small amount of impurities present in the electrolytic iron, the properties of the alloys prepared may be considered to be due solely to the presence of the alloying elements. The alloys were prepared by melting the electrolytic
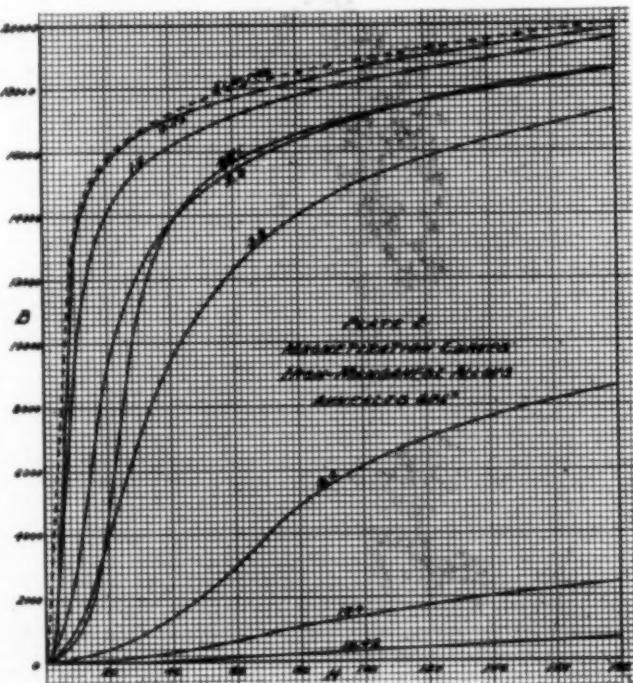
FIG. 2.—MAGNETIZATION CURVES, IRON-MANGANESE, ANNEALED 675°.

iron, together with the other desired element, in a covered magnesia-lined graphite crucible, bedded in an electric resistor furnace. The ingot, about 1 lb. in weight, was then forged into a rod under a steam hammer. Two bars were obtained for tensile strength tests and one for the magnetic measurements.

The following alloys with manganese were tested:

Bar	% Managese Added	Analysis
123H	0.50	0.505
170A	1.0	
170B	2.0	
170C	3.0	
144V	3.5	
123I	4.0	4.514
170D	6.0	
170E	8.0	
170F	10.0	
123J	11.9	10.419

Analyses have been made upon but three of the samples as indicated above. However, in these three instances, the intended and actual percentages are in reasonably close agreement, and it may be assumed, especially since manganese and iron are closely allied, that the bars not analyzed have a manganese content approximately as indicated by the added percentage.

All of the alloys forged readily at normal heats. Bars with 0.50 per cent and 1 per cent manganese were soft and machined easily with ordinary lathe tools, but it was somewhat difficult because of their hardness. Above 3 per cent of manganese it was necessary to resort to grinding to work the forged pieces into finished test bars.

Tensile strength tests were made on only three of the bars, the results being as follows:

Bar	%MN	Stress per sq. in. Elas. Limit	Ultimate	Per cent Red. Area	Elongation
123H	0.505	45200	57300	76.6	31
123I	4.514	196000	196000	0	0
123J	10.419	64500	88800	4.1	6

These figures can hardly be used as a basis for discussion, except that they bear out the general conclusion obtained in tests of commercial materials. Addition of 0.50 per cent of manganese has caused but little variation from the results with pure iron; at 4.51 per cent Mn we are in the region of great strength and brittleness, as is indicated by the high ultimate strength and the negligible elongation. At the highest percentage of manganese (10.42) the material still has high ulti-

the discussion above. The retentivities increase as a result of annealing at 675°, decrease at the high heating of 1000°, and again increase with the quenching at 900°. For bar 123H (0.50 Mn) the coercive forces become less with each annealing, and there is little change after quenching. But for other bars the values of coercive force decrease with annealing at 675°, increase after heating to 1000°, and again become less after quenching at 900°.

TABLE I.—DATA OF MAGNETIC TESTS.

Bar	Comp %	H=10				H=20				H=50				H=100			
		Unann.	Ann. 675°	Ann. 1000°	Quench 900°	Unann.	Ann. 675°	Ann. 1000°	Quench 900°	Unann.	Ann. 675°	Ann. 1000°	Quench 900°	Unann.	Ann. 675°	Ann. 1000°	Quench 900°
123H	0.50	9,850	13,000	11,300	10,700	14,300	15,600	14,550	14,400	16,950	17,400	16,600	16,850	18,300	18,400	17,900	18,150
170A	1.0	4,850	9,700	5,400	.....	11,000	14,000	11,200	.....	16,100	16,700	15,800	.....	18,200	18,000	17,800	.....
170B	2.0	1,350	3,100	1,100	.....	5,100	9,200	3,750	.....	12,500	14,700	11,350	.....	15,700	16,700	15,350	.....
170C	3.0	650	1,150	900	.....	1,900	4,000	3,150	.....	8,150	11,050	10,750	.....	12,200	14,550	14,650	.....
144V	3.5	1,100	850	950	.....	3,500	2,700	3,050	.....	10,600	10,150	9,800	.....	13,700	13,600	13,550	.....
123I	4.51	150	800	500	900	500	4,600	1,300	3,350	6,150	14,900	5,250	13,700	12,100	16,800	10,600	16,400
170D	6.0	200	.....	.....	.....	600	.....	.....	.....	3,950	.....	.....	.....	10,150	.....	.....	.....
170E	8.0	150	150	50	.....	350	400	100	.....	1,900	2,100	750	.....	5,450	6,100	1,750	.....
170F	10.0	0	50	150	0	0	100	200	.....	100	450	450	.....	500	1,400	1,300	......
123J	10.42	0	0	0	0	0	0	0	0	0	50	50	150	0	300	300	500

mate strength, but a greater toughness, shown by the elongation of 6 per cent.

The magnetic tests were made upon an Esterline permeameter, under four conditions of heat treatment, viz.: as forged, after annealing at 675° C., after annealing at 1000° C., and after quenching at 900° C. All results are compared to a standard bar of forged electrolytic iron in its unannealed state. The curve for this sample is indicated by a dotted line, and material of a quality equal to this standard is of very high grade.

The magnetic tests data are indicated in Tables I and II and Plates 1, 2, 3 and 4. In the unannealed condition the alloys show a successive deterioration in permeability with increasing manganese content, until at the maximum percentage, 10.42 (123J), the bar is non-magnetic. Bars 123H and 170A, with 0.50 per cent and 1 per cent, are not greatly inferior to the standard, this being especially true of 123H, and the discrepancy is still less after the annealing at 675°.

This annealing has resulted in a marked betterment of magnetic quality for all bars, the increase being most striking for bar 123I (4.51 per cent Mn). Bar 123J (10.42 Mn) becomes slightly magnetic and remains so throughout the succeeding tests, but it may be regarded as a non-magnetic alloy.

The second annealing at the higher temperature of 1000° has caused a considerable decrease of permeability of all bars and for all values of the magnetizing force; in fact, the materials are in practically the same condition as when raw forged. This decrease is most striking for the 4.51 per cent Mn bar, as was the previous increase.

But three of the bars have been tested in the quenched con-

TABLE II.
COERCIVE FORCE AND RETENTIVITY.   H(max.)=200

Bar	Comp'd %	Coercive Force				Retentivity			
		Unann.	Ann. 675°	Ann. 1000°	Quench 900°	Unann.	Ann. 675°	Ann. 1000°	Quench 900°
123H	0.50	6.5	5.7	4.5	4.8	11,000	12,500	9,700	10,100
170A	1.0	9.6	6.9	7.0	....	10,800	14,700	9,000	....
170B	2.0	19.2	12.5	16.0	....	10,500	11,600	8,800	....
170C	3.0	28.7	23.0	24.0	....	8,500	9,800	9,600	....
144V	3.5	20.8	28.0	24.5	....	7,600	10,600	8,900	....
123I	4.51	41.5	23.0	45.2	23.9	8,600	15,000	8,000	12,900
170D	6.0	50.8	...	...	...	9,200	...	...	...
170E	8.0	58.7	57.5	65.0	....	5,200	6,100	2,000	....
170F	10.0	90.1	70.7	80.0	....	1,100	1,800	1,900	....
123J	10.42	Non.	103.0	121.0	78.5	Non.	400	500	800

dition, and the only important feature is the great improvement in bar 123I (4.51 Mn), which has been restored to its best condition, as obtained after the first annealing at 675°. Whether this is due to any direct effect of quenching or to the reheating at the lower temperature of 900° is problematical.

The values of coercive force and retentivity, as indicated in Table II, follow most closely the fluctuations pointed out in

The deductions to be drawn from these tests may have an important bearing upon certain problems in the manufacture of steel for electrical purposes, particularly steel castings. It is well known that there is a decided lack of uniformity in this material, and experience shows that numerous concerns have difficulty in making castings of this class, although for other purposes their product is of high grade. Our results indicate a falling off in the magnetic quality of the alloys with an increase of manganese. For a percentage of 0.50 the permeability is but slightly less than that of the standard electrolytic sample. At 1 per cent Mn the quality has become appreciably less, and on further increase to 2 per cent the alloy is of comparatively low grade.
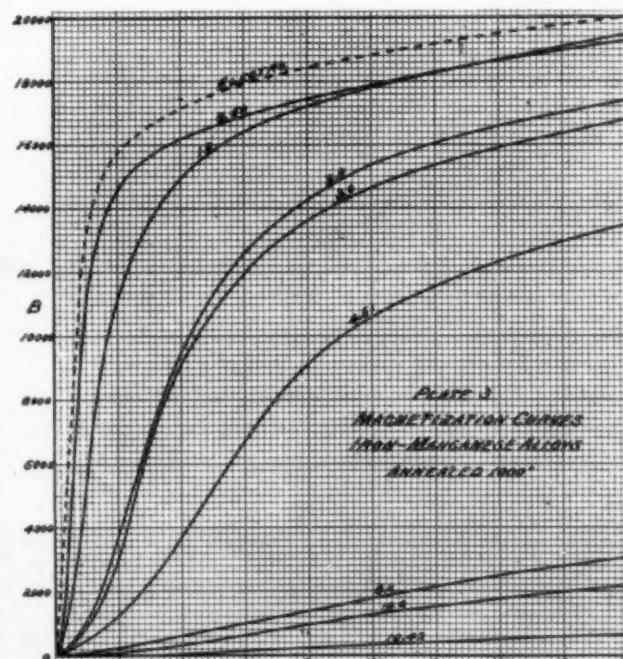
FIG. 3.—MAGNETIZATION CURVES, IRON-MANGANESE, ANNEALED 1000°.

If this be true in the above series, might it not be that in commercial material where the carbon and other elements are by no means negligible that the limits of manganese content are even more closely drawn than our results indicate, and are thus very often overstepped, particularly in foundry practice? It is beyond question that any addition of manganese is a detriment. Why, therefore, in steels for electrical work, where

in general strength is of secondary consideration, adhere to manganese additions? Cannot the sulphur be reduced to the lowest possible limits, and cannot the oxidation be taken care of by addition of an element such as silicon, an excess of which has a beneficial effect? Or will not the electric refining furnace solve the whole problem?

But of greater bearing than the actual manganese content is the marked susceptibility of these alloys to variations in the
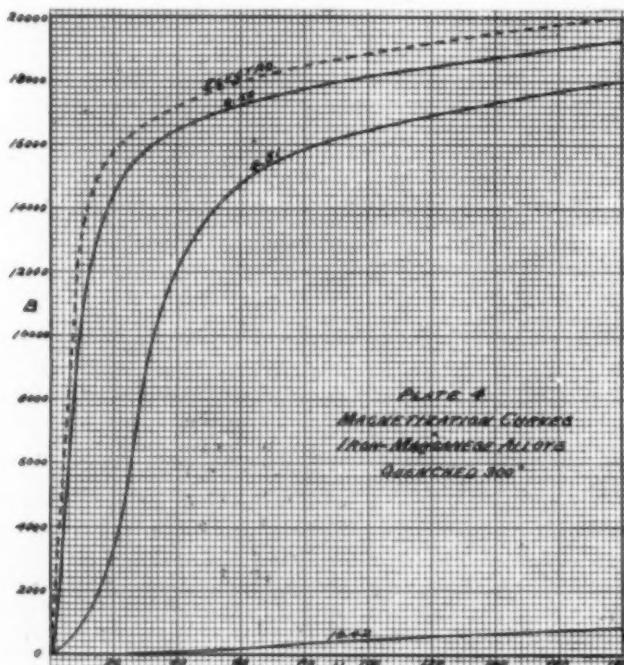
FIG. 4.—MAGNETIZATION CURVES, IRON-MANGANESE, QUENCHED 900°.

heat treatment. Judicious annealing at low temperatures may be of greatest benefit to material which would otherwise be condemned, while an overheating may spoil a good material or nullify the effect of heat treatment. This factor may be relevant in commercial work, where very often castings are not annealed at all; and in other cases the annealing is done without skilled supervision or without the check of a pyrometer. Or, even if carefully conducted, the temperatures used, while suitable for general work, may be too high for the electrical steels.

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The "Pinch Effect" in Electric Furnaces of the Induction Type.

By JOH. HARDEN, E. E.

Carl Hering and E. F. Northrup* have on various occasions dealt with the "pinch effect." It might, therefore, be of interest to electrochemists to obtain a few practical figures relating to this matter.

It is, of course, very difficult to give the actual conditions under which the phenomena occurred, because, as Mr. Hering points out, so many factors will influence its appearance and the brevity of its duration tends to make an exact and reliable observation almost impossible. There is, therefore, little wonder if the practical results do not correspond closely with the theoretical formulas given by Hering and Northrup, nor is it, therefore, to be concluded that these are incorrect or misleading. On the contrary, the figures given here rather support these theories.

*Electrochem. and Met. Industry, Vol. V, p. 223; VI, p. 383; VII, p. 266, 271, 369.

The data referred to here was obtained in a 60-kw induction furnace of the Kjellin type, designed and operated by the Gröndal-Kjellin Company, of London; this furnace is now erected at the Sheffield University, in the Department for Applied Science.

The furnace has a total capacity of about 3 cwt. (300 lb.) and is operated with single-phase alternating current, 55 cycles to 60 cycles.

The "pinch effect" was observed when melting scrap and pig iron preparatory to a steel-melting test. The approximate section of the bath was, when the phenomena occurred, as follows: width, 1¾ in.; depth, 2½ in., hence cross-section 4.375 sq. in. The bath was nearly rectangular, the bottom being somewhat narrower than the top.

The metal contained about 2 per cent carbon, and the temperature was estimated at about 1400° C.

The primary coil consisted of 23 turns; the primary current was 220 amp. If we assume that the leakage field, etc., consumed about 10 per cent of the ampere-turns, which on other occasions was found to be practically correct, we find that the secondary current was 4450 amp. The current density was consequently about 1020 amp. per square inch, which might seem rather low, but if we consider that the resistance of the iron is increased with more than 0.5 per cent for every degree above red heat, we find that this density is in reality not so surprisingly low.

The level of the bath commenced to recess on a certain point, showing a cavity of about ⅝ in. deep. Curiously enough this occurred on several occasions on the same spot; when the lining was examined after the furnace had cooled down, it was found that a small piece of cinder, fused to the wall of the lining, was the cause of a slight distortion of the bath section on this spot and this undoubtedly was the cause of the contraction on this particular place.

As the temperature rose to a bright white heat, the agitation became more violent, until suddenly a complete rupture took place, followed by a loud report and a severe shaking of the furnace body. A strong flash was at the same time observed, the level of the metal rose to about 1½ in. above the average on both sides of the rupture and the metal rushed down these hills with great rapidity. The bath closed again immediately after the rupture, but as soon as the surfaces were touching they were again separated before full contact was obtained, causing a rapid clatter, but of less violence than the first.

If allowed to go on, the metal soon froze, because of the oxidation caused by the flashing, which in a short time prevented further contact. In that case it was very difficult to again establish the contact and resume the melt; in fact, as the phenomenon once occurred under a strong slag blanket, which was used for refining purposes, it was found impossible to finish the melt and the charge had to be broken out. The instruments were hunting violently during the occurrence, jumping between maximum and zero so that no readings could be taken.

It was soon found, however, that this annoying feature could be effectively avoided in the case of iron melting; if, as soon as the first tendency to recessing appeared in the bath the power was lowered, say, 5 per cent to 8 per cent, and a handful of small pieces of pig iron, of about the size of a pea, which was kept ready for the purpose, was thrown into the cavity the temperature of the metal was so much lowered on the dangerous spot that a rupture was avoided. By carefully continued charging of iron it was then always possible to reach a point when rupture would no more take place with the power available.

If the bath was filled to its normal depth of about 6 in. it was not possible to obtain the "pinch effect" with the total power available of 63 kw. It might in this connection be of interest to make a few remarks about the general agitation of the bath, due to the combined effect of the heat and the magnetic influence.

In the first place, there is a kind of rolling motion, i.e., a rotation of the mass of metal around the longitudinal axis of the bath. This is caused, in all probability, to a great extent by the so-called "Thomson effect," and which is very prominent in an ordinary "constant-current" transformer. The stray field has a tendency of lifting the metal out of the hearth and as the charge is liquid a rolling action is thus produced.

This can, to a certain extent, be modified by shifting the position of the primary coil, but as a good mixing of the bath is effected by this rolling, it is not desired to check it too much. In a large furnace, however, the agitation may be so excessive as to shorten the life of the lining, if special precautions are not taken.

This action is accelerated by the effect of the temperature; the inner circumference of the bath is shorter than the outer, and also its radiation surface is smaller, hence the local heating is somewhat greater in this portion of the bath, the more so as owing to the shorter length of the inner circumference the electric resistance is also smaller and the current density, therefore, perhaps somewhat greater; this may, however, to a certain extent, be counterbalanced by the distribution of current due to the electro-magnetic repulsion between the primary and secondary.

This latter is causing another disturbance of the bath level; the secondary conductor, formed by the molten metal ring, has a tendency to increase its diameter owing to the mutual action of the fields set up by the primary and secondary currents. The result is that the metal is thrown toward the outer wall of the hearth, causing the level on the outer circumference of the bath to rise, sometimes as much as 8 per cent to 10 per cent. This is especially the case when dealing with metals of lower melting point than that of iron, because the high fluidity of well-heated liquid steel makes it more subject to the influence of the rising effect on the inner wall caused by the temperature action.

This phenomenon may very often have annoying consequences. When the lining has to be repaired it is always found that the crucible wall is very much more attacked on the inner circumference, just about the level of the bath, than compared with the outer circumference.

This is due to the slag which accumulates along this line, because, as it has a much higher resistance than the molten metal, practically no current passes through it and it, therefore, slides down the inwardly inclining surface of the steel toward the inner crucible wall. It is also only subjected to the ascending action of the local heat mentioned, and, therefore, is thrown up on the side of the lining, fluxing with the magnesite and thus causing the annoyance. Fortunately, this can be avoided by using a neutral slag, which is quite permissible, as no refining is generally required in these furnaces.

Finally, a third class of rotation can also be observed in the bath. This is shown by the fact that if a lump of some material with a higher melting point, such as a piece of ferrochrome, is thrown in at the front of the hearth, the lump will soon be found to have traveled round to the back of the furnace opposite the spout, and may even make a complete revolution before it is finally absorbed. This shows that the molten ring is also rotating around the primary coil in the direction of the longitudinal axis of the bath.

This rotation is rather slow; in a 1½-ton furnace, operated with single-phase alternating current of 16 cycles, the velocity is about 1 ft. to 2 ft. per second. It is always moving in one and the same direction in the same furnace; its cause may be somewhat difficult to explain without carrying us too far, but it is possible that it is analogous to the effect in a synchronous motor, or else similar to that occurring in a rotary converter, which is started from the alternating-current side, while the armature is short-circuited. At any rate, this rotation is highly beneficial for the proper mixing of the metal; it is especially prominent in a three-phase combined furnace of the Roechling-Rodenhauser type, where the agitation is so

strong sometimes that steps must be taken to check it.

Stassano employs, as is well known, a mechanical contrivance to rotate the whole furnace so as to obtain a similar mixing effect.

The pinch effect was further observed when dealing with copper and brass. The melting of the former was entirely frustrated in an ordinary magnesite lining. The hearth was first heated by means of a welded steel ring; after this had been removed, it was sought to establish a permanent bath by pouring in molten copper from a graphite crucible heated in a coke fire. A quantity of graduated copper was kept ready for replenishing. Before the bath was formed, however, the ring snapped off and the metal gradually froze. The primary current was 400 amp; the secondary calculated to be 8280 amp and the current density about 1650 amp per square inch. It may, however, have been a good deal higher locally, owing to the very strong agitation of the metal before snapping.

I might mention, however, that I have seen copper being treated, though with difficulty, in another furnace, but here the crucible, though made of fireclay, had a depth of about 8 in. or 9 in., while the average width was only about ⅞ in. Here the pinch effect could not so easily take place, but the difficulty in handling a bath of this shape made the furnace practically useless, besides the heavy heat losses by radiation.

The next trial with a view to studying the pinch effect was made with brass. This was more successful, as it was quite possible to obtain a liquid bath, but the pinch effect was readily obtained when forcing the current.

The bath section was 5½ in. x 1¾ in., or about 9.5 sq. in. The "pinching" commenced under violent agitation of the whole bath, i.e., with an approximated density of only 530 amp per square inch. It is quite likely, however, that the density was again much greater at the moment of the "pinching" owing to the strong agitation of the bath, otherwise it could hardly be accounted for.

The zinc fumes which were liberated when the rupture took place caused some difficulty in re-establishing good contact; however, by throwing in small pieces of scrap brass and slightly lowering the current the pinch effect could be tolerably avoided.

In the meantime a very effective arrangement has been devised by the writer whereby all the disturbing effect of this phenomenon is completely avoided; it is even possible to treat copper by this means without the slightest difficulty and with a comparatively shallow bath. Owing to a pending patent application the nature of the device cannot for the present be divulged, however.

In a larger induction furnace with a charge of 2 tons to 3 tons the pinch effect is very rarely observed, except if the melting is very much forced during the period of recharging, in which case it may occur. The rupture, however, is of little importance, because the heat capacity of the remaining bath is sufficiently large to procure a good contact should a rupture take place.

Again, in the case of the combined furnace of the Roechling-Rodenhauser type, the pinch effect has not been observed in regular operation as far as is known. It is also very unlikely that this should be the case, because, in the first place, the furnace is practically always started by pouring in a charge of molten metal, which at once fills up the channels to the normal level. At the beginning, before the furnace is properly heated, all the heat will be generated by the inductive current in the channels only, but in a very short time the coating on the cast-steel plates will become conductive and as soon as this takes place the channels are relieved as from one-third to over one-half of the total power will pass through the bath in this way; a contraction of the middle portion of the bath is, of course, impossible because, apart from the fact that the large section of metal prevents such a course, the heating is in this part of the furnace convected from the said coating and not generated by the current directly in the steel.

This fact also explains why the word "electrodes" for the

cast-steel plates would be somewhat misleading; these plates are only part of the conductors by means of which the auxiliary secondary current is conveyed from the copper cables to the conductors of second class formed by the magnesite coating attached to them. This coating will be heated by the passing of the current through the refractory mass, exactly in the same manner as a Nernst glower is heated; it seems incongruous to call the holders of a Nernst glower "electrodes" as this term is generally associated with an arc or an electrolyte. The current density in the bath, conveyed to it in this way, is much too low to cause any appreciable amount of heat.

London, September, 1909.

A Theoretical Study of the Efficiency of Direct Heat Dryers.

By John Jermain Porter.

By direct-heat dryers are meant those dryers in which the gases of combustion come into direct contact with the material to be dried, and form the vehicle which removes the moisture. The temperature of these gases is necessarily a function of the quantity of excess air admitted to the burning fuel.

All direct-heat drying operations may be divided into three classes:

1. Those in which the heated gases which do the drying and the moist material to be dried move continuously and in the same direction through the apparatus. This class we may term parallel current dryers.

2. Those in which the heated gases and the moist material move continuously through the apparatus, but in opposite directions. These are countercurrent dryers.

3. Those in which the operation is not continuous, the water or moist material being present in definite quantity and the hot gases being passed over it until it is all evaporated. This may be called the intermittent form of dryer.

Each of these forms is a separate problem when it comes to deriving an expression for the amount of evaporation and in determining the conditions of maximum efficiency.
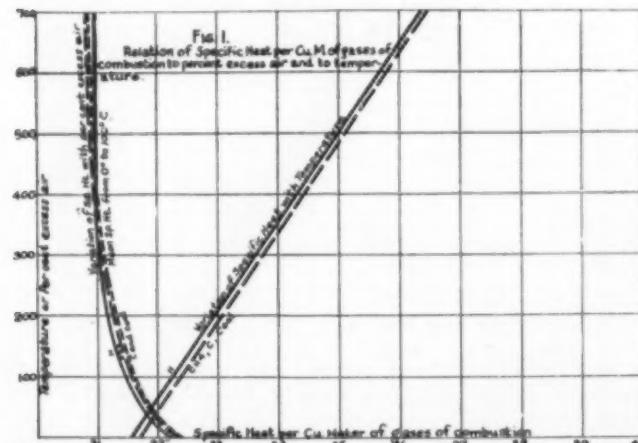
FIG. 1.—RELATION OF SPECIFIC HEAT PER CUBIC METER OF GASES OF COMBUSTION TO PER CENT EXCESS AIR AND TO TEMPERATURE.

In all of the calculations of this paper the following symbols will be used:

H Heat of combustion per unit of fuel in kilogram calories, water uncondensed.

M Kilos of water formed by the combustion of one unit of fuel.

M_1 Kilos of water evaporated from M per unit of fuel.

W Kilos of water added to dryer, per unit of fuel.

W_1 Kilos of water evaporated from W per unit of fuel.

T Total kilos of water evaporated per unit of fuel, $= W_1 + M_1$.

D Kilos of solid substance added to dryer per unit of fuel.

V Cubic meters of gases of combustion, under standard conditions, per unit of fuel.

V_1 Cubic meters of water vapor, under standard conditions, resulting from the combustion of one unit of fuel.

s_1 Specific heat of gases of combustion.

s_2 Specific heat of solid substance added to dryer.

t Temperature at which gaseous products leave dryer.

t_1 Temperature of gases of combustion on entering dryer.

t_2 Temperature of water and solid added to dryer.

t_3 Temperature at which solid and excess of water leave dryer.
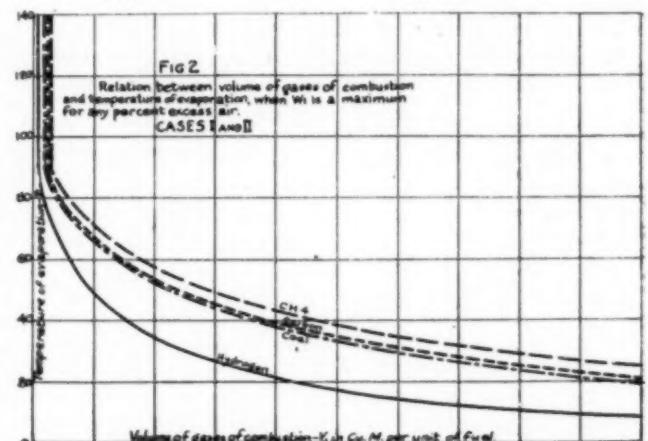
FIG. 2.—RELATION BETWEEN VOLUME OF GASES OF COMBUSTION AND TEMPERATURE OF EVAPORATION, WHEN W₁ IS A MAXIMUM FOR ANY PER CENT EXCESS AIR.

pp Partial pressure of water vapor in gaseous products leaving dryer.

Lt Latent heat of evaporation of water at any temperature t.

n Number of units of fuel burned per minute.

m Total number of minutes of drying (in case III).

m_1 Number of minutes in first phase, heating up stage (case III).

m_2 Number of minutes in second phase, evaporating stage (case III).

C Kilogram calories of heat lost through radiation and conduction per unit of fuel burned.

I. The Parallel Current Dryer.

If we assume that a sufficiently intimate contact of gases and substance to be dried is obtained, then there are two self-evident facts which may be stated as axioms and which furnish a basis on which to work. First, all products leave the dryer at the same temperature. Second, as long as water is in excess (i.e., as long as liquid water escapes from the discharge end of the dryer) the gases escaping will be saturated with water vapor.

Since the heat in the incoming substances is equal to the heat in outgoing products plus the heat lost by radiation and conduction, we have, using metric units:

$$H + 606.5 M + W t_2 + D t_2 s_2 = (V - V_1) t s_1 + D t s_2 +$$
$$(W - W_1) t + (M - M_1) t + W_1 (606.5 +$$
$$0.305 t) + M_1 (606.5 + 0.305 t) + C \qquad (1)$$

This is the general equation which applies to every possible condition.

As an additional condition of evaporation it is necessary that the volume of gases must be sufficient to carry off the water vapor formed, or the volume times the partial pressure must be equal to or greater than the volume of water vapor present. Therefore:

$$T = \text{or} > \left(\frac{V - V_1}{1 - pp} pp \ 0.81 \right) \qquad (2)$$

As an aid in clearing up our ideas on this subject let us for

a time look at it from another standpoint, first reducing our dryer to the simplest possible conception.

First, we will render the dryer independent of time by conceiving it a simple box, in which we introduce a weight of water W, at an initial temperature t_2, and then a volume of gas V, containing H heat units. The box is then closed up and shaken until the contents reach a state of equilibrium at some final temperature t. This is essentially the same thing as the parallel current dryer, since by repeating this operation each
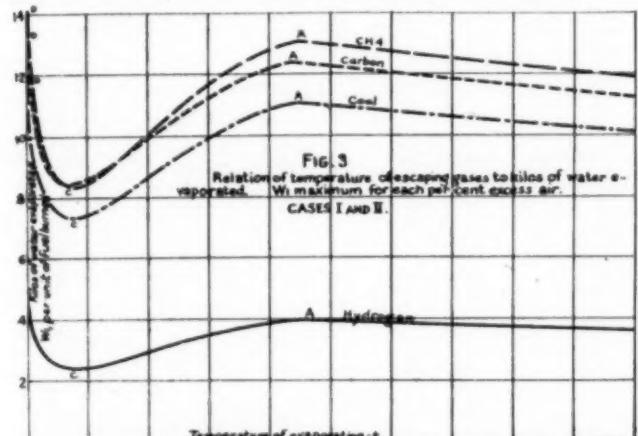
FIG. 3.—RELATION OF TEMPERATURE OF ESCAPING GASES TO KILOS OF WATER EVAPORATED. W_1 MAXIMUM FOR EACH PER CENT EXCESS AIR.

interval of time and making the intervals infinitely small we have the continuous process.

Now, keeping V constant in our box, but varying W, let us see what happens.

First, with W infinitely large it is evident that there can be no rise in temperature above t_2, or $t = t_2$, and if the gas contains moisture (as from the combustion of hydrogen containing fuels) there will not only be no evaporation, but there will be precipitation, or W_1 the water evaporated, will be a minus quantity.

As we make W less, t gradually rises above t_2, and the precipitation, or value of $-W_1$, decreases until finally, at some certain value of W, t reaches the dew point of the gas, and there is neither precipitation nor evaporation, or $W_1 = O$. Decreasing W still more t continues to rise, and as t is now above the dew point of the gas some evaporation takes place. The amount, however, is given by the equation

$$W_1 = \frac{V pp - V_1}{1 - pp} 0.81,$$

and much of the heat supplied in the gas is wasted as sensible heat in the excess water, as given by the third term of equation (1).

Finally, a point is reached at which W is just equal to W_1 and at the same time the gases pass out saturated; t at this point is evidently the temperature of maximum efficiency, or T and W_1 equal a maximum, since in order to get a higher temperature we must continue to reduce W, and, hence, also W_1 and T. It is also evident that above this temperature the gases are no longer saturated with moisture.

Evidently now we have three variables upon which evaporation depends—V, W, and t; t is dependent on both V and W, and if one of these be held a constant, is directly a function of the other.

For the maximum efficiency of evaporation ($T =$ a maximum) there are two conditions to be fulfilled; first, $W = W_1$; i.e., there must be no excess water to carry out sensible heat from the dryer. Second, V should have the smallest possible value, so as to avoid carrying out more sensible heat than is necessary in the gases.

Now, the maximum for the value of V is limited by equation

(2), hence, for the maximum efficiency this may be written as an equality and we may then substitute (2) in (1) and get an expression giving V in terms of t when W_1 and T are at the maximum for any t or vice versa.

Doing this and remembering that T equals $W_1 + M_1$, we get

$$H + 606.5\,M + Wt_2 + Dt_2\,s_2 = (V - V_1)\,ts_1 + Dts_2 +$$
$$(W - W_1)t + (M - M_1)\,t +$$
$$(606.5 + 0.305\,t)\left(\frac{V - V_1}{(1 - pp)}\right)pp\,0.81 + C. \tag{3}$$

This equation does not, of course, hold for temperatures above a certain limit. As t rises V must become less in order that the gases may still be saturated. Now, when V is reduced to the minimum resulting when the fuel is burned with the theoretical amount of air, if t is still raised the gases will not be saturated, (2) will not be an equality, and (3) will not hold true. Evidently, then, we have (3) giving us the relation between W, V, and t for maximum evaporative efficiency up to some certain value of t, while above this value of t we must fall back on equation (1), remembering that V in this case is a constant, and equal to that formed when the fuel is burned with the theoretical air.

Finally, it is evident that for the lower range of temperatures where the gases are saturated

$$W_1 = \left(\frac{V - V_1}{1 - pp}pp - V_1\right)0.81, \text{ which reduces to}$$

$$W_1 = \left(\frac{V pp - V_1}{1 - pp}\right)0.81. \tag{4}$$

II. The Counter Current Dryer.

The case of the counter-current dryer is different in that the excess of water or moist material need not pass out at the same temperature as the discharged gases, since they leave at opposite ends of the apparatus. The general equation, therefore, becomes

$$H + 606.5\,M + Wt_2 + Dt_2\,s_2 = (V - V_1)\,ts_1 + Dt_2\,s_2 +$$
$$(W - W_1)\,t_2 + (M - M_1)\,t_2 + W_1\,(606.5 +$$
$$0.305\,t) + M_1\,(606.5 + 0.305\,t) + C. \tag{5}$$
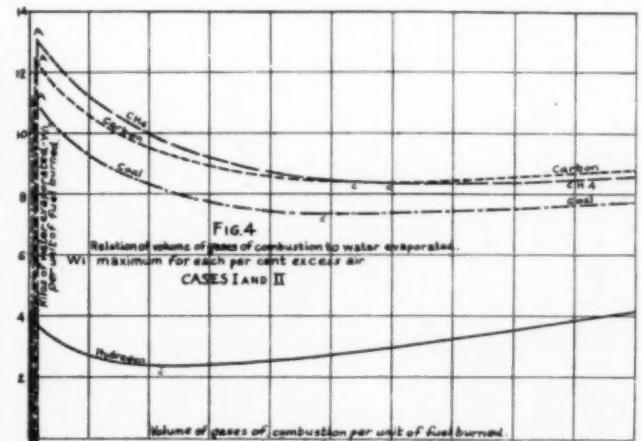

FIG. 4.—RELATION OF VOLUME OF GASES OF COMBUSTION TO WATER EVAPORATED. W_1 MAXIMUM FOR EACH PER CENT EXCESS AIR.

As before we have $T =$ or $> \left(\dfrac{V - V_1}{1 - pp}pp\,0.81\right)$ \hfill (2)

and for T maximum for any t

$$H + 606.5\,M + Wt_2 + Dt_2\,s_2 = (V - V_1)\,ts_1 + Dt_2\,s_2 +$$
$$(W - W_1)\,t_2 + (M - M_1)\,t_2 + (606.5 + 0.305\,t)$$
$$\left(\frac{V - V_1}{1 - pp}\right)pp\,0.87 + C. \tag{6}$$

As before (6) is true up to some certain value of t, above this we must fall back on (5), while below it equation (4) is also true.

III. The Intermittent Dryer.

(t_1 greater than 100° C.)

In order to evaporate a weight W_1 of water we must first raise this water, and the solid D with which it is associated, to the temperature at which evaporation is to take place. During this period the gases will be discharged at a constantly rising temperature, varying from t_2 to t, and equal on the average to $\frac{t-t_2}{2}$. If the gas has a dew point below t_1 the heat absorbed during this period will be

$$W(t-t_2) + Ds_2(t-t_1) + V\frac{t}{2}s_1 nm_1 + nm_1 C, \quad \text{where} \quad m_1 \text{ is}$$

the time of this phase.

After W has reached the temperature t evaporation may be assumed to begin (although in reality it has been going on right along) and the heat carried out is equal to $W_1 Lt + Vs_1 tm_2 n + nm_2 C$, where m_2 is the time of this phase.

Our general equation between heat supplied and heat absorbed and carried out then becomes

$$Hnm + Wt_2 + Ds_2 t_2 = V\frac{t}{2}s_1 nm_1 + Dts_2 + Wt +$$
$$W_1 Lt + V s_1 tnm_2 + nmC. \quad (7)$$

But $W = W_1$, therefore $Wt + W_1 Lt = W_1(606.5 + 0.305 t)$, and so

$$Hnm + Wt_2 + Ds_2 t_2 = nVs_1(m_1\frac{t}{2} + m_2 t) + Dts_2 +$$
$$W_1(606.5 + 0.305 t) + nmC. \quad (8)$$

This expression is strictly correct even in case there is a condensation of water from V during the beginning of the operation. In this case the heat evolved by this condensation is later absorbed in the evaporation of the same water. That is, $606.5 M = M_1 t + M_1 Lt$. It is not considered necessary to combine this equality with equation (8), since in this case M_1 must always equal M. Also, the fact that the gases may be less in volume than V at the beginning of the operation (owing to condensation of part of V_1) is exactly counterbalanced by increase in volume above V later on due to reëvaporation of this water.

It would seem now that as long as there is sufficiently intimate contact between gases and water or moist material that the gases must leave the drying chamber saturated with water
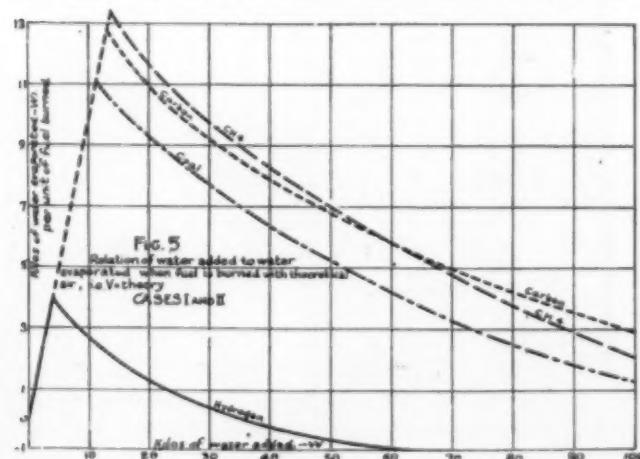
FIG. 5.—RELATION OF WATER ADDED TO WATER EVAPORATED WHEN FUEL IS BURNED WITH THEORETICAL AIR, I.E., V = THEORY.

vapor. This is true during the first part of the heating-up stage, but is not true the latter part nor after equilibrium is reached, simply because the heat contained in a given volume of gases is not sufficient to evaporate enough water to saturate them. This is true even in the special case where the incoming gases are at a temperature below 100° C. and which will receive separate attention later on.

In case III proper, when the temperature of the incoming

gases is greater than 100° C. the temperature of evaporation t is, during the second stage of the operation, always equal to 100° C. This seems self-evident, since the water must rise in temperature, as fresh additions of heat are brought in by the incoming gases, until the boiling point is reached, after which absorption of latent heat of evaporation keeps the temperature constant until the water is all vaporized.

Hence, putting $t = 100$ in (8) we get as our final equation for this case:

$$Hnm + Wt_2 + Ds_2 t_2 = 50 Vns_1(m_1 + 2m_2) + 100 Ds_2 +$$
$$637 W_1 + nmC. \quad (9)$$

Case IIIA. Intermittent Dryer.

(t_1 less than 100° C.)

A special case of the intermittent dryer is found when the
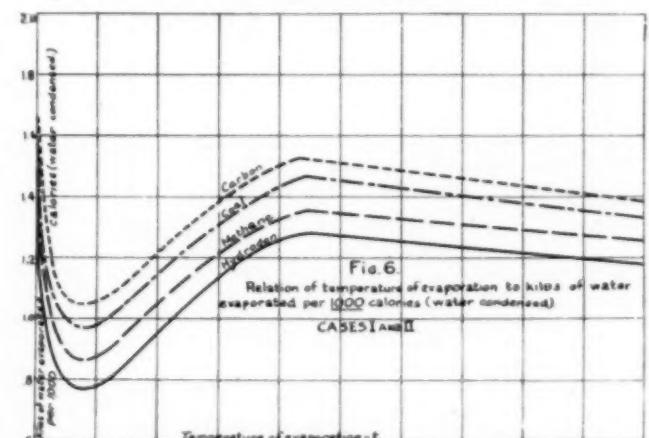
FIG. 6.—RELATION OF TEMPERATURE OF EVAPORATION TO KILOS OF WATER EVAPORATED PER 1000 CALORIES (WATER CONDENSED).

incoming gases are at a temperature of less than 100° C. In this case V is a function of H and t_1 and cannot be considered an independent variable.

$$Vs_1 t_1 = H, \text{ or } V = \frac{H}{s_1 t_1} \quad (10)$$

Equation (8) still holds good and substituting (10) in this we get

$$Hnm + Wt_2 + Ds_2 t_2 = \frac{nH}{t_1}(m_1\frac{t}{2} + m_2 t) + Dts_2 +$$
$$W_1(606.5 + 0.305 t) + nmC. \quad (11)$$

But in this case t will always equal t_1 just as the evaporation is completed; i.e., the temperature will continue to rise first rapidly, then slowly, approaching but never quite reaching t_1 until the last of the water is just evaporated. In other words, we may say $t = t_1$, and $m_1 = m$, $m_2 = 0$. Therefore,

$$Hnm + Wt_2 + Dt_1 s_2 = \frac{Hnm}{2} + Dt_1 s_2 + W_1(606.5 +$$
$$0.305\frac{t_1}{2}) + nmC. \quad (12)$$

The gases are, of course, only saturated during the first part of the operation.

We have now succeeded in deriving formulas for the several systems of drying, by the use of which we may find the amount of water evaporated for any given set of conditions. It remains now to determine the conditions of maximum efficiency, or conditions under which the greatest amount of water is evaporated per unit of fuel burned.

In order to accomplish this we may determine W_1 maximum for each t or V and plotting these a curve will be obtained which will show the efficiency of evaporation at every temperature and, of course, the conditions of maximum efficiency. The same result might also be accomplished by the calculus.

I have worked out these efficiencies on the basis of four fuels,

to wit, hydrogen, methane, carbon and a bituminous coal of analysis

Carbon .... 70 per cent.
Hydrogen .... 6 per cent.
Oxygen .... 12 per cent.
Nitrogen .... 2 per cent.
Ash .... 10 per cent.

These fuels were chosen as representative of all classes and as giving the maximum possible range of water in the gases
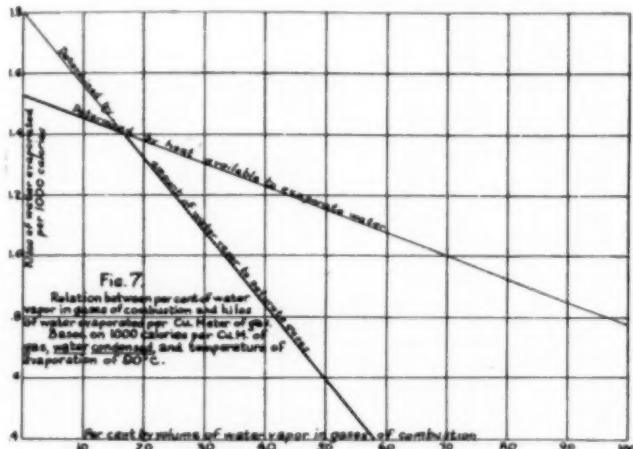
FIG. 7.—RELATION BETWEEN PER CENT OF WATER VAPOR IN GASES OF COMBUSTION AND KILOS OF WATER EVAPORATED PER CUBIC METER OF GAS. BASED ON 1000 CALORIES PER CUBIC METER OF GAS, WATER CONDENSED, AND TEMPERATURE OF EVAPORATION OF 90° C.

of combustion. The units chosen are 1 cu. meter for the gaseous and 1 kilogram for the solid fuels.

Since for comparisons of this sort it is necessary to set some numerical value for the quantities D, C and t_2 I have chosen the simplest possible values, that of zero in each case. s_1, the specific heat of the gases of combustion, is, of course, a variable depending not only on the composition of the gases, but also on the temperature. However, the variation is so slight over the range of temperature ordinarily used in drying and over the possible range of composition that I have considered it permissible to give it the constant value of 0.32 (for 1 cu. m.) in all cases. Fig. 1 shows the variation in specific heat of the gases of combustion of the four fuels considered with varying temperature and percentage of excess air, and will confirm the statement just made concerning its unimportance. Except in the case where it is desired to show the effect of excess water upon efficiency we may also put $W = W_1$, since it is self-evident that this is necessary for maximum efficiency for any per cent excess air. In cases III and III A to make the results comparable to cases I and II we can take n and m each equal to 1, so that $m_1 + 2 m_2 = 2 - m_1$.

Introducing these values in our general equations we get the following simplified equations:
(1) reduces to

$$W_1 = \left(\frac{H + 606.5 M - (V - V_1)\, 0.32\, t}{606.5 + 0.305\, t} \right) - M_1. \quad (13)$$

(3) reduces to

$$V = \frac{H + 606.5 M}{\dfrac{(606.5 + 0.305\, t)\, pp\, 0.81}{1 - pp} + 0.32\, t} - V_1 \quad (14)$$

(4) remains unchanged.

The equations of Case II, i.e., (5) and (6), become the same as those simplified for Case I, i.e., as (13) and (14), respectively. This since Case II differs from Case I only in that the solid and excess water may pass out at a different temperature from that of the gases in Case II. If the amount of solid

and excess water is made zero the difference between the two cases disappears.

In case III (9) reduces to

$$W_1 = \frac{H + 16\, V\, (2 - m_1)}{637} \quad (15)$$

In case III A (12) becomes

$$W_1 = \frac{H}{2 \left(606.5 + 0.305 \dfrac{t_1}{2} \right)}$$

The following table gives the values of some of the quantities involved in these expressions for each of the fuels considered.

|	1 Cu.M. Hydrogen	1 Cu.M. Methane	1 Kilo. Carbon	1 Kilo. Coal
H (water uncondensed) Kg. Cals......	2613	8598	8100	7245
M (equals M_1) Kilos.................	.81	1.62	0	.54
V (fuel burned with theoretical air) Cu. Meters	2.905	10.62	8.91	7.89
V_1 Cu. Meters	1.	2.	0	.667
s_1	.32	.32	.32	.32

Taking up first Cases I and II there are four variables to be considered, to wit: W_1, W, V and t. First considering $W = W_1$ (i.e., W_1 a maximum for each per cent excess air) the relation between V and t is given by (14) and the results expressed graphically are shown in Fig. 2. Note that with rising temperature the volume of gases decreases to the minimum, which results when the fuel is burned with the theoretical air. The volume, of course, remains constant at this minimum value for any further increase in temperature of evaporation.

Fig. 3 shows the relation between temperature of evaporation (i.e., temperature of escaping gases) and water evaporated. Note the double maximum. At zero we have an apparent maximum, which results theoretically because at that temperature no heat is carried out by the escaping gases *except as latent heat* in the aqueous vapor, hence all the heat furnished is used in evaporating water. As the temperature rises above zero the evaporation falls off rapidly to a minimum, which occurs at about 16° C. Above this it rises rather rapidly, to a second maximum at about 90° C. This is the practical maximum which should be aimed at in the operation of dryers, and is obtained when the fuel is burned with the theoretical air and W is so proportioned as to keep the gases just saturated without having any excess water pass out of the dryer unvaporized. Beyond this point as t increases the evaporation slowly decreases, the gases being no longer saturated, and,
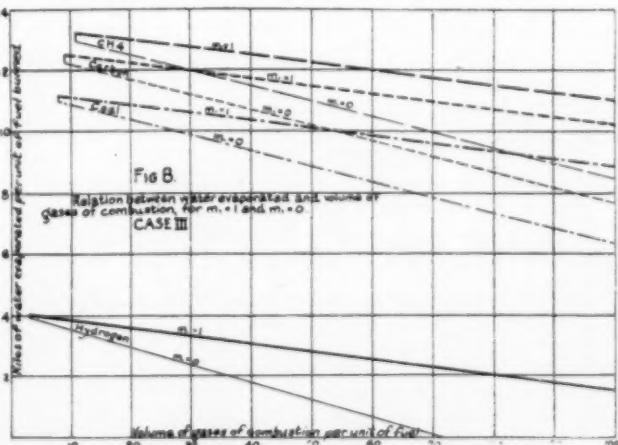
FIG. 8.—RELATION BETWEEN WATER EVAPORATED AND VOLUME OF GASES OF COMBUSTION, FOR $M_1 = 1$ AND $M_1 = 0$.

therefore, carrying out more sensible heat than they should. The data for Fig. 3 are calculated by means of equations (4) and (13). (4) applying from 0° to the second maximum and (13) beyond this point.

Fig. 4, which shows the relation between volume of gases of combustion and water evaporated, corresponds exactly to Fig. 3 and may be constructed from Figs. 2 and 3. The parts AB of the curves in Fig. 4 correspond to those parts to the right of

A on the curves of Fig. 3. The minima are the points C on each figure, while the maxima occurring at $0°$ on Fig. 3 are off the diagram on the right of Fig. 4.

Fig. 5 brings in the other variable, W, which we have heretofore taken as equal to W_1. If the water added is greater than can be evaporated, it carries out sensible heat and decreases still further the evaporative power. If, on the other hand, it is less than could be evaporated, W_1 is again less than the maximum possible, since W_1 cannot be greater than W.

Fig. 6 is a comparison of the four fuels on the basis of an equal number of heat units. It gives the relation between temperature of evaporation and kilos of water evaporated per 1000 calories of heat developed. The data may be obtained from equations (13), (14) and (4) modified by substituting for

$$H + 606.5\,M, \text{ 1000 calories; and for } V, \frac{1000\,V}{H + 606.5\,M}$$

It will be noted that the form of the curves is exactly similar to those of Fig. 3, but the four fuels are now arranged with respect to their hydrogen content, that giving rise to the least water in the gases of combustion per 1000 calories developed having the greatest efficiency.

In Fig. 7 I have shown the relation between the per cent of water vapor in the gases of combustion and the evaporative power under given assumed conditions as to heat contained in a unit volume of gas and temperature of evaporation. It will be noted that for low percentages of water vapor the amount of evaporation is determined by the quantity of heat available in the gases, i.e., by equation (13), while for larger percentages of water vapor the evaporation is determined by equation (4), the quantity of water vapor which can be held by the gases. The position of the line AB, and hence of the point C, will, of course, vary with the quantity of heat per cubic meter of gas, while the position of the line XY, and hence again the point C, will vary with the temperature of evaporation.

Coming now to Case III the variables are W_1, V and m_1. Fig. 8 shows the relation between volume of gases of combustion and water evaporated for the two cases $m_1 = 1$—that is, very slow heating—and $m_1 = 0$—that is, very rapid heating. The maximum efficiency is seen to be obtained when the fuel is burned with the theoretical air and with slow heating. It is interesting to note that theoretically the efficiency of evaporation is not affected by the amount of water in the gases of
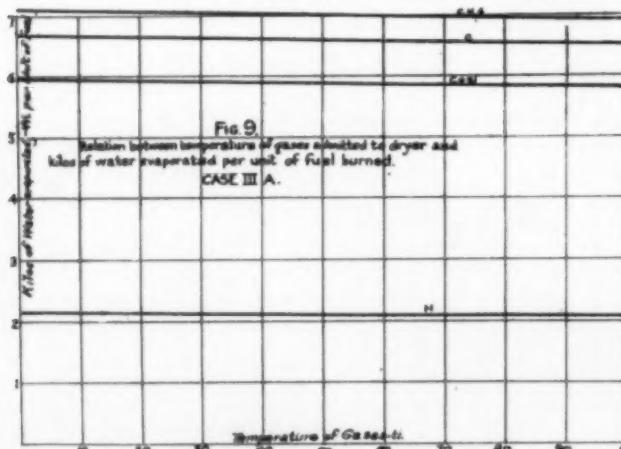
FIG. 9.—RELATION BETWEEN TEMPERATURE OF GASES ADMITTED TO
DRYER AND KILOS OF WATER EVAPORATED PER UNIT
OF FUEL BURNED.

combustion except in so far as affected by the term H, which, it will be remembered, is heat of combustion water uncondensed.

In Case III A, there are only two variables, W_1 and t. The relation between these two is shown in Fig. 9, and it is seen that there is only a very slight drop in evaporative efficiency with increased temperature of evaporation.

Finally, in Fig. 10, I have shown the comparative efficiencies of the several classes of dryers. From this it will be seen that there is but little to choose between the continuous and intermittent types as far as efficiency is concerned, but that the low temperature intermittent dryer has an efficiency only about half that possible with the other forms.

In conclusion, let us summarize the practical lessons which we may learn from this theoretical study, bearing in mind, however, that some of our assumptions will not hold strictly true in practice.
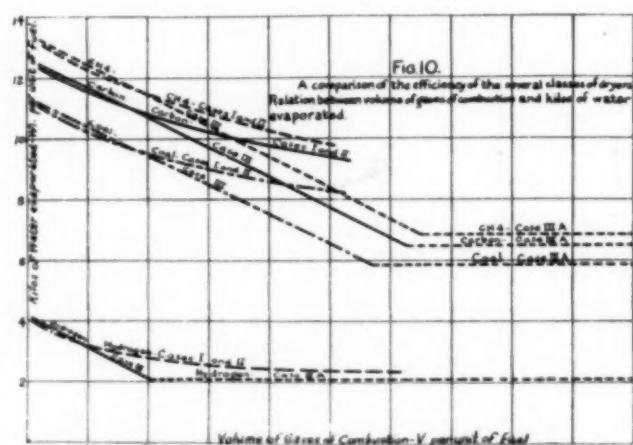
FIG. 10.—A COMPARISON OF THE EFFICIENCY OF THE SEVERAL
CLASSES OF DRYERS. RELATION BETWEEN VOLUME OF GASES
OF COMBUSTION AND KILOS OF WATER EVAPORATED.

First, the conditions of maximum efficiency for the parallel current dryer are found when the fuel is burned with the theoretical amount of air, the temperature of the escaping gases is about $90°$ C., and no excess water escapes from the discharge end of the dryer. A temperature of escaping gases of from $80°$ C. to $120°$ C. will give a satisfactory economy.

Second, in the case of the counter-current dryer the conditions are somewhat different, since here the solid dried materials must pass out at a temperature approximating or equal to the temperature of the gases of combustion as they enter the dryer. The temperature of these gases will be at the maximum when the fuel is burned with the theoretical air, hence the maximum heat will be carried out by the dry solids under this condition

The conditions for getting maximum efficiency will, therefore, depend on the amount of solid and its specific heat, as well as on the other variables previously discussed, and only in case pure water is being evaporated can the counter-current dryer have a possible efficiency equal to that of the parallel current form.

Third, in the intermittent dryer I have assumed perfect heat exchange between the hot gases and moist material in the dryer. It is more difficult to realize this condition in this than in the other forms of dryers; in fact, impossible in most cases. Hence, the practical efficiency of the intermittent dryer will invariably be less than that shown and less than the parallel dryer when properly operated.

The conditions for maximum efficiency are slow heating up, and fuel burned with as nearly as possible the theoretical amount of air.

Fourth, low-temperature direct-heat dryers must necessarily have a very low efficiency, only about half that possible with other forms.

Fifth, the presence of hydrogen in fuels decreases materially their value for drying purposes. For use in dryers fuels cannot be properly valued on the basis of heat units alone, but should be compared as to drying efficiency by means of the equations here given.

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Cementation.

BY ALFRED SANG.

Cementation.—"The fact that alloys can be formed by the union of two metals at a temperature below the melting point of the more fusible of the two, has long been known to metallurgists."[1] Records of that knowledge go back to the year 1820.[2]

The two most widely used processes of cementation are those of malleableizing iron and manufacturing blister steel, so-called on account of the blistered appearance of the surface; the even distribution of these small blisters is an indication of uniform carburization. These blister-bars, which are used in making the finest grades of crucible steel, such as cannot be produced from the best open-hearth billets of the same composition, absorb carbon to a considerable depth by being buried in charcoal and heated for seven to eleven days, depending on the degree of carburization desired—at a temperature of about 1000° C.; it takes two to three days to bring the furnace up to heat and about fourteen to cool it slowly down. The dilation of the metal by heat produces porosity and favors diffusion. The subsequent melting in crucibles distributes the carbon throughout the metal and ensures homogeneity. In the case of "shear steel" the bars are simply piled and welded together.[3]

According to Prof. Arnold, it is impossible to introduce much over 2 per cent of carbon into iron by cementation, even after repeated treatments. Case-hardening is a form of cementation to give a hard skin to objects which are to undergo severe wear, but no blisters are formed. Blisters do not appear either when remelted iron or mild steel are treated, because the slag has been eliminated by previous treatment; it is the action of the carbon on the slag which raises the blisters, carbonic oxide being formed in the body of the metal softened by heat.[4]

Theories of Cementation.—Sydney Marsden has classified the theories of cementation as follows:[5]

1. By the occlusion of gases, a theory first proposed by Lepkay,[6] carbonic oxide (CO) is supposed to lose some of its carbon to the iron, thereby being converted into carbonic dioxide (CO_2), after which, through contact with the carbon, it is reduced back to carbonic oxide.

2. By the direct combination of the carbon with the iron by contact to form a carbide; this theory makes it very difficult to understand how the operation progresses toward the center of the metal treated.

3. By the inter-solution of the carbon and iron. It is difficult to believe that the low temperature of the process will induce sufficient molecular activity to bring about such a result within a reasonable period of time. Roberts-Austen has favored this view.

4. By the diffusion of the carbon through the iron, which is rendered porous by heating; this is Marsden's own theory and was founded on his experiments on the diffusion of carbon through red-hot porcelain. This theory would seem to require that the carbon be present in the pores of the iron in a very finely divided state, but this hardly justifies the claim that on this account no carbide can be formed. Diffusion may be the means of securing intimate contact and other proper conditions for a chemical reaction of which a hardening carbide would be the result.

Auguste Laurent[7] had claimed that the carbon must be present as a gas to produce cementation, but the temperature of the process being far below the point of volatilization of carbon, he concluded that it must be present as carbonic oxide. This was later authoritatively confirmed by H. Behrens.[8] It

is important to note, however, that M. F. Margueritte discovered[9] that diamond in contact with iron would also bring about cementation, but *only at the points of contact*, thus proving the diffusion of carbon through iron in immediate contact with it, at a temperature very far below its point of volatilization. It is evident that the laws of contact action must be scrutinized for an explanation. Capt H. Caron[10] claimed that in all cases a cyanide must be formed to cause cementation; to supply the cyanogen (CN) both carbon and nitrogen would in this case be indispensable to the process.

While the theory of diffusion is the most acceptable one, the question as to whether it is a carbide or the carbon itself which is diffused, still remains open. A commercially useful rate of diffusion takes place as low as 800° C., but the action is most rapid between 1000° and 1100° C. If the diffusion depends, as is most likely, on the condition of the iron as well as on that of the carbon, this temperature should be the best, from the point of view of the iron, for cementation by any element.

Electro-Cementation.—J. Garnier inquired into the effect of an electric current on the process of cementation; his first experiment[11] consisted in placing pieces of iron and retort carbon in contact, the iron being the negative pole; after applying a current of 7 volts and 55 amp. for several hours, signs of cementation were found. His next experiment[12] was to place two iron bars (analyzing 0.001° C.) 0.4 inch apart, with charcoal dust between them, then heating to the usual temperature of cementation and applying a current of 2.5 volts and 55 amp. for three hours, he found that the piece of iron forming the negative pole was cemented to a considerable depth, but the one forming the positive pole had remained unchanged.

This result would seem to indicate very clearly that cementation is at least partly due to contact electricity; the cementing material or "cement" must, at the temperature of working, be positive to the metal treated. In the same way a high-carbon steel will carburize iron heated in contact with it. The action is reversed in the case of malleableizing; the carbon is withdrawn from the iron by heating it in contact with fine hematite ore. The carbon or cement-metal will travel in the negative direction of the contact current set up. The current causes apparently a true convection of molecules which have been dissociated by an effect of the porosity of the hot iron similar to that of zinc dust, spongy platinum and other catalytic decomposing agents. Solution of these molecules does not have to take place if their dissociation can be brought about without it.

Dry Galvanizing or Cementizing.—The inventor of the first practical process of galvanizing by cementation, now commonly known as dry galvanizing or cementizing, was Miles Berry, an Englishman, from whose British patent, dated 1838 (No. 7630), I quote as follows:

"The alloying or changing of metals by cementation is a process well known in metallurgy, but I am not aware that any metal has ever been before so changed or protected by this process that it would resist the action of air, or humidity, or of certain acids, whereas copper and iron, both wrought and cast, and other oxidizable metals, when they have been subjected to the said process, according as the same is modified to suit each particular description of metal, resist all these sources of oxidation.

"And first, as regards copper, after it has been cleansed it is placed in a furnace covered with a mixture of charcoal and powder of zinc, and the temperature then raised to cherry red,[13] which degree of temperature is kept up for a longer or shorter period, according to the bulk of the article or to the desired thickness of the coating and color to be given to the article. The operation is one of great nicety, for which I am

[1] Roberts-Austen: An Introd. to the Study of Metall. Ed. 1902, p. 72.
[2] Faraday and Stodart: Quarterly Jl. of Sci., vol. IX (1820), p. 319.
[3] See Harbord & Hall: Metall. of Steel, Ed. 1905, p. 220 & foll.
[4] Dr. Percy: Jl. Iron & St. Inst., vol. I (1878), p. 116.
[5] Jl. Chem. Soc., April, 1881.
[6] An. de Ch. et de Ph., Yr. 1846.
[7] An. de Ch. et de Ph., Vol. 65 (1837), p. 427.
[8] Oesterr. Zeits, fur Berg- u. Huttenwesen, vol. XLIII, p. 198.

[9] An. de Ch. et de Ph. Yr. 1865, p. 75.
[10] An. de Ch. et de Ph. October, 1860.
[11] Hillairet: bef. Soc. Intern, des Elec.; Ind. & Iron, vol. XV, p. 182.
[12] C. R., vol. CXVI, p. 1449.
[13] 700° C. (1292°F.) corresponds to "full cherry-red" (Howe).

informed no definite rules can be laid down, but that experience will enable any competent workman to perform it with sufficient exactness. It will be found that in every case there is a point at which the copper, when taken out of the furnace is perfectly inoxidizable, whereas, if the operation last too long, the produce is nothing but common brass very readily oxidized."

He then goes on to describe a method of dipping iron in a fused alloy of 3 parts copper and 2 parts zinc, after which the articles are heated to redness in charcoal dust until zinc fumes cease to be given off; they are then plunged in water and allowed to cool slowly. A third process which he claims, is to pulverize the above alloy when cold and dip the iron articles previously smeared with oil or grease into this powder, and then to heat them in charcoal dust. I quote further from his patent as follows:

"A fourth variety of the process is to dip the iron into a solution of sulphate of copper (after being perfectly cleaned) and to suffer it to remain there for a time. As soon as the iron is covered with a sufficient covering of precipitated copper, it is taken out, plastered with potter's earth mixed with water, and then covered with a layer of pulverized zinc and borate of soda, or other substitute for the same, or the pulverized zinc, borate of soda, or other substitute may be made into a paste with the clay and water, and the article smeared over with the said paste. The iron is then placed in the furnace covered with charcoal powder and heated to white heat for some minutes. The rest of the process is the same as before described. The metals thus rendered inoxidizable are either of a gold or silver hue, according to the length of the operation or the quantity of zinc that combines with the copper. The brightness of the gold color alloy may be enhanced by rubbing the article with vegetable charcoal, or the soot from a wood fire, and nitric acid. It is proper to add, that instead of pulverized zinc, I have been informed pulverized calamine[14] may be used."

The broad claim is then made of a process for "alloying by cementation . . . . by which copper, iron and other oxidizable metals are preserved from oxidation, their surfaces are changed in appearance and also rendered more brilliant."

Berry's observation, that a zinc salt-like silicate of zinc could be used instead of the metallic powder, was borne out in Dumas' discovery of a process for galvanizing by heating the object to redness in a closed retort with zinc oxide and powdered charcoal.[15] To iron and cast-iron articles he gave a slight coating of copper by immersion in a solution of sulphate of copper; the film of copper was necessarily converted into brass. If a piece of copper wire is placed in zinc oxide and heated in a closed retort, it is in a very short time converted into a very brittle brass.

It is, therefore, evident that the modern process of sherardizing is a sort of combination of the ideas of Berry & Dumas, the articles being buried in zinc dust (oxidized zinc powder) or in zinc powder, to which zinc oxide is added, and then heated to a dull red heat.[16]

Early Attempts.—The following extracts from British Patent No. 1963, of 1864, granted to Neil McHaffie, for a method of treating iron plates for shipbuilding and boiler-making and wrought iron in other forms, are interesting.

"For these purposes the wrought iron, whether it be in the form of plates or sheets, or forged or fashioned to any desired shape, is surrounded with oxide of iron, or oxide of iron ore, or with oxide of manganese, or oxide of zinc, or matters containing these or similar metallic oxides or substances, and the whole is heated by preference to a full red heat;[17] it is maintained at this temperature for many hours, and afterward is gradually cooled. The wrought-iron plates, sheets, forgings

or other pieces will by this treatment be found to have undergone a peculiar change, which enables them to resist more or less completely destructive or corrosive influences."

He recommends air-tight "troughs of iron," and states that the treatment should be continued from 12 hours to three days, depending on the nature of the articles. He prefers using oxide of iron, and states that the work, on being immersed for a length of time in sea water, is found to be free from shell fish or marine animals, and also, in a degree, from corrosion or rust.

Mr. Isaac E. Craig, of Camden, Ohio, has taken out several patents for improvements in methods of cementing iron sheets by means of carbon and metallic oxides, to render them rust-resistant. In one[18] he packs oxide of antimony, tin or lead between the sheets and then heats them to redness, after which they are "burnished, rolled or hammered in the usual way." In another[19] he claims a deoxidizing of sheets, followed by their alloying by applying to the surface a composition of carbon and one or more of the same oxides, and heating to redness in a furnace. In a third patent[20] he claims the coating of the sheets with carbon, and any or a combination of the same oxides previous to the final heat and working.

In Craufurd's patent of 1837, for hot galvanizing, the process of using pulverized zinc as a paint was included. In a patent of de Fontainemoreau, of 1838, the following method for preparing the powder is given:

"The zinc is put into a reverberatory furnace, every opening for the admission of the atmospheric air carefully closed, and the temperature of the melted zinc raised to a degree approaching red heat. The door is then opened and the zinc skimmed, after which one-tenth of its weight of wrought (not cast) iron filings moistened with muriatic acid (to which some sal ammoniac may be added) is thrown into the fused metal, which must be stirred all the while; after the introduction of the filings the surface of the metal must be covered over with fine charcoal powder and the temperature carried to about the cherry-red heat, at which temperature the metal must be maintained for one hour, stirring it occasionally with an iron poker. The melted metal is then conveyed into a brick or cast-iron trough, covered over with a lid of cast iron to exclude all contact with the atmosphere; the metal is then stirred by means of an iron rod passing through a hole in the cast iron door until by cooling it becomes so solid that it can be stirred no longer; when quite cool it is ground into powder, and the more friable it is the better the operation has succeeded. The powder so obtained will preserve from oxidation copper and iron, polished and filed steel, such as clockwork, articles of hardware, ironmongery, etc., by merely covering the articles with the powder, and this, even though they should be exposed to wet or damp. The zinc may be also applied through the medium of a paint or paste, in manner which I shall next proceed to describe: The powder of zinc is mixed with any of the unctuous substances generally used in paints and varnishes. The substances which have been found to answer best are those which were conductors of galvanic fluid, and hence this has been commonly called galvanic paint. Very good paint is to be made with oil distilled from the refuse tar of the gas manufactories, adding one-third of spirit of turpentine; oil varnish may also be used, but it is very expensive; linseed oil may be employed as it is in common paint, but is not quite so favorable to the galvanic effect of zinc; lead or ceruse may be added to the paint to give it some consistence. The proportions of the materials of the paint depend on the substances with which the zinc powder is mixed, and on the uses to which the paint is to be applied. With the same powder a paste may be made; by rubbing copper, steel or polished iron with the same they will be effectually protected. This paste is

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[14] Silicate of zinc ($H_2 Zn_2 Si O_5$).
[15] Bull. Soc. Ch. et Ph., vol. IV (1865), p. 374.
[16] 550° to 625° C. (1022° to 1157° F.) corresponds to "dull-red" (Howe).
[17] Full cherry-red, or 700° C. (1292° F.).

[18] U. S. Pat. No. 237,963, of 1881.
[19] U. S. Patent No. 241,529, of 1881.
[20] U. S. Patent No. 321,693, of 1885.

made with melted wax, into which is put ten times its weight of powder of zinc and about one-fiftieth of tallow or oil.

"For protecting small polished metal articles I employ a zinc paper or wrapper, manufactured by mixing powder of zinc ground very fine with the pulp of the paper while making, or by powdering common paper previously covered with some glutinous substance, such as gum or flour paste, taking care always to exclude the use of animal glue, which has a tendency to cause the iron to rust."

Various combinations of the rusts of zinc, lead, antimony and copper have been proposed as anti-fouling compounds, when mixed with a suitable fluid medium.[21]

Present-Day Methods.—Protective coatings obtained by cementation with metallic dusts, have been carried out for many years in a commercial way. Sheet-steel cow-bells have been given their brass coating and their tone by packing them in finely divided brass and charcoal dust, contained in a plumbago retort, which is made air-tight by luting with clay. The retort is then heated in a furnace. It has been found in the case of gold that simply rubbing the articles with gold dust would leave a deposit.[22]

The author has found that a brass dust[23] of a beautiful green color could be prepared for coating iron articles at low temperatures by mixing zinc dust and copper dust and heating the mixture at a low heat in an air-tight retort; the copper dust was obtained as a fine purplish-brown precipitate, by adding zinc dust to a solution of copper sulphate, the exchange of the metals taking place instantly with evolution of heat; special care is required in the drying to prevent the formation of too much oxide. It was found that the brass dust could be used repeatedly without deterioration and without the necessity of adding a hydrocarbon to the charge; the coating obtained by this method is smooth and homogeneous and of a golden color; it adheres so well that the pieces can be bent and hammered without the slightest evidence of scaling. If instead of brass dust a mixture of zinc and copper dusts is used, the articles have a first coating of pure copper blend;ng into an outer coating of zinc; the mixed dusts are more or less converted into brass dust, and if the heat is too great beads of brass are formed.

Copper dust obtained by the method just described can be used for coating metals by cementation. When copper is precipitated by adding zinc to a copper sulphate solution, there is a slight but continuous evolution of hydrogen, as already observed by Leykauf in 1840, and a basic zinc sulphate is formed. According to Lothar Meyer[24] there is no cuprous oxide formed. J. B. Senderens found[25] that in 10 per cent only of all cases of metallic precipitation which he investigated was the precipitation even approximately that of equivalent for equivalent. A careful study of the properties of copper sulphate solutions and the precipitation of metals has been made by R. M. Caven.[26] His results accord with those of Lothar Meyer, excepting that he detected the presence of cuprous oxide.

The process of Sherardizing has been described elsewhere.[27]

Diffusion Under Pressure.—Prof. Walthère Spring, of Liège, has studied the effects of high pressure on pulverized solids,[28] and discovered that alloys could be produced by compressing the intimate mixture of the dusts of the component metals; his work in that direction, which was very thoroughgoing, was confirmed by Sir W. Roberts-Austen[29] and supplemented by the researches of Fawsitt[30] and Lehmann,[31] and the general results have been embodied in a masterly report by

Prof. Spring before the International Congress of Physics of 1900.[32]

The following are the observations of Prof. Spring in the case of finely divided zinc:[33]

"Zinc filings will be completely welded under 5000 atmospheres (75,000 lb. per square inch); the mass scarcely commences to flow under 7000 atm. (105,000 lb. per square inch).

"The binding of the zinc filings deserves close observation, because, taking place as it does with great difficulty, it is readily understood that after all it only depends on the intimate contact of the particles. All phenomena observed with zinc apply to other bodies without exception.

"Under a pressure of 700 atm. (10,500 lb. per square inch), a slight degree of binding is observed; the block can be taken from the press, but it is easily broken and will then disintegrate. Examined under the microscope under 500 diam. of magnification one can readily detect *voids between the grains;* they only touch at a few points. Under 2000 atm. (30,000 lb. per square inch) the cohesion is such that the block can be filed, but when hammered it will break. The break, when examined under the microscope, still shows some voids between the grains, but they are far less numerous; on the other hand, in many places thorough agglomeration is evident. Under 4000 atm. (60,000 lb. per square inch) the number of voids has dwindled further. Only very few are to be found, and they are difficult to trace; under 5000 atm. (75,000 lb. per square inch), the block is a perfectly continuous mass which can be put in a vise and be filed and hammered like a block produced by fusion.

"I then compressed zinc powder at a temperature of 130° C. (266° F.), the temperature at which the metal is most malleable. The powder was even more closely welded and the block showed a crystalline break."

The molecular diffusion giving rise either to agglomeration of similar or alloying of dissimilar powders, is considerably aided by friction of the particles among themselves or against the walls of the dies. The oxides of the metals cannot be pressed into a continuous mass,[34] and in that respect zinc dust acts as an oxide and cannot be pressed into a solid mass of zinc at ordinary temperature; it is compressed into a crystalline mass at a temperature of 130° C., but this is due to peculiar conditions which are peculiar to zinc dust (see footnote 27).

Diffusion Without Pressure.—Diffusion will take place and alloys will be formed without compression of the dusts if they are brought into intimate contact,[35] but the operation is slow. This applies to sheet metals also. The action can be hastened by even a moderate application of heat, far below the temperature of fusion of the metals in contact; after from 3 to 12 hours of contact, Spring obtained a perfect weld; in the case of zinc and copper the metals were alloyed to a depth of .25 mm. The bearing of the principles underlying the diffusion of solid metals on galvanizing by cementation is evident.

A law due to Hallock,[36] which seems to be correct as far as it goes, but does not explain a multitude of phenomena, because it disregards several important limiting factors, such as exposed surface and physical variations of the metals, is as follows: "An alloy can be produced out of its original constituents without considerable pressure if the temperature be above the melting point of the alloy, even if it be far below the melting point of the most easily fusible constituent."

Iron and Steel Institute.

The autumn meeting of the Iron and Steel Institute was held in London from Sept. 28 to Oct. 1. In the following we give abstracts of the papers presented:

[21] e. g. Engl. Pats. No. 16,107 of 1890, and No. 9,417, of 1891.
[22] Zeits. für Instrumentenbau, vol. 3, p. 238.
[23] Patented.
[24] Deuts. Chem. Gesell. Berlin, vol. 9, p. 512.
[25] Bull. Soc. Chim. 3° Ser., vol. 17, p. 271.
[26] Jl. Soc. Chem. Ind., vol. 19 (1900), p. 18.
[27] See EL. CHEM. & METALL. IND., vol. 5 (1907), p. 187; vol. 6 (1908), p. 189.
[28] Jl. Phys. Soc. Yr. 1882, p. 231.
[29] Deuts. Chem. Gesell., vol. XV (1882), p. 595.
[30] Dingl. Pol. Jl., vol. CCXXXII, p. 482.
[31] Wied. Ann., vol. XXIV (1885), p. 5.

[32] Rap. Cong. Int. Phys., vol. I., p. 412.
[33] Abstract in An. de Ch. of de Ph., Yr. 1881, p. 185.
[34] L. Henry: Phil. Mag., 5th Ser., vol. XX (1885), p. 81.
[35] W. Spring: Bull. Acad. Roy. Belge., 3° Ser., vol. XXVIII (1894), p. 23.
[36] U. S. Geol. Survey, Bull., 60 (1890).

A report of the discussions which followed the presentation of the papers and a general report of the proceedings will be found elsewhere in this issue in the letter from our London correspondent. (See page 491.)

Dry Blast.

Two papers dealing with dry blast were presented by Mr. GREVILLE JONES and Mr. R. S. MOORE.

Mr. Jones' paper on "uniform moisture in blast" is a report on an experiment carried out at the Clarence Iron Works in 1909, on the question whether the principal saving in fuel in the Gayley dry-blast process is due to uniformity of blast or to its dryness. The results are in favor of the latter assumption.

Mr. R. S. Moore discusses "the fuel economy of dry blast as indicated by calculations from empirical data." In referring to the above-mentioned experiments, he points out that the results of the test strongly point to the fact that the great heat saving of the Gayley dry blast must be due to its dryness. The theoretical explanations on this basis have not been supported by any actual experimental proof, and they have apparently been as much rejected as accepted.

The principal experimental proof which is lacking is data on the saving of fuel to be secured by adding heat to the bosh. In studying the conclusions suggested by the test it occurred to the author that this hiatus is supplied by the results of experience with the Neilson hot blast.

Fig. 1 is a curve representing the relation between temperature of hot blast and coke saved on cold-blast requirements, the data for the points from which this curve is plotted being taken from Sir Lowthian Bell's book on "The Principles of the Manufacture of Iron and Steel."

A curve which represents the variations of coke consumption with heat added to the blast, also represents the combined effect of all physical and chemical changes taking place in the blast furnace, whether the heat changes have to do with carbon
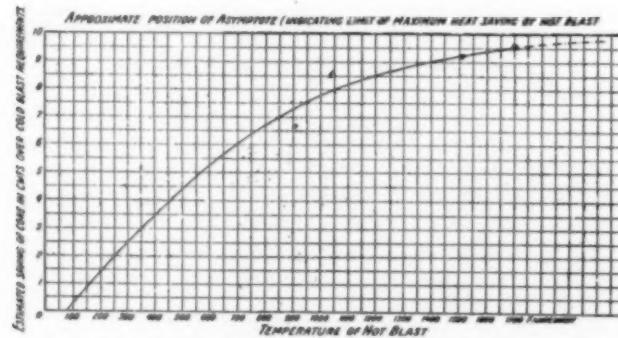

FIG. 1.—TEMPERATURE OF HOT BLAST AND COKE SAVING.

monoxide reduction, the carbon reduction, or the heat absorbed by the iron, the slag, or by heating stock. It is, therefore, a curve of practice rather than of theory, in so far as it is accurately plotted.

It is evident from the slope of the initial portion of the curve that a saving of 1 cwt. of coke is obtained for approximately each 100° Fahr. increase of blast temperature. The heat added in the blast per 100° per ton of iron is 276,000 b.t.u. One hundred and fifty-four thousand b.t.u. are required per ton of iron to disintegrate 1 grain of moisture per cubic foot in the blast. This heat is, therefore, equivalent to $154,000 \div 276,000 = 0.56$ cwt. on the initial portion of the curve.

But the saving in the upper portion of the curve is less than $\frac{1}{2}$ cwt. per 100° Fahr., and the question now arises: What portion of the curve applies to the heat necessary to disintegrate moisture? It is a well-known fact that for the economical reduction of iron oxide in the blast furnace, as large a proportion as possible must be reduced by carbon monoxide.

Now, as this reduction occurs most readily at about 1100°,

and decreases rapidly at higher temperatures, and as the temperature of the stock entering the furnace soon approaches this point, it follows that a limit to the amount of heat which should escape in the gases rising from the bosh is soon reached. It was pointed out by Sir Lowthian Bell years ago that the economy of the Neilson hot blast was due to the fact that adding heat to the blast enabled it to supply much of the heat necessary in the bosh to melt the iron and slag. The heat which was thus absorbed did not have to pass through the upper carbon-monoxide reducing zone, thereby heating it and retarding the reduction.

Now, the heat which the iron and slag require is only about 18 per cent of the total; it appears self-evident, therefore, that the fewer heat units which are added to the blast, the easier it is for the iron and slag to absorb them before they pass out of the bosh; but as the 18 per cent is approached more and more escape to the reduction zone. Therefore, removing the moisture before it enters the furnace is equivalent to utilizing all the heat necessary to disintegrate it in melting the iron and fusing the slag. The economy to be expected from low moisture alone is, therefore, that represented by the initial portions of the curve, or 1 cwt. of coke for 100° Fahr. temperature of blast, or, as pointed out before, 0.56 cwt. per grain of moisture per cubic foot.

If 5 grains be taken as the average amount of moisture which can be eliminated, this would be equivalent to $5 \times 0.56 = 2.8$ cwt.; $2.8 \div 20 = 14$ per cent of 20 cwt. per ton of iron.

About 2 grains of moisture were added to secure uniformity and no gain or loss was found except a very slight lowering of the silica, indicating that the harmful effect of the 2 grains added was almost neutralized.

If it be assumed that the heat gain due to uniformity is equivalent to one-half of this, or to the effect of 1 grain, the foregoing considerations would account for a saving of about 17 per cent of fuel for dry blast. It may be said that a saving of 2.8 cwt. on 28 cwt. coke consumption on cold-blast is not necessarily equivalent to a saving of 2.8 cwt. on 20 cwt. hot-blast consumption.

There must, of course, be some difference, but it is probably very slight, because, while under cold-blast consumption 40 per cent more coke is burned than under hot-blast, 50 per cent more ore is contained in the furnace under hot-blast conditions. Therefore, while there is less carbon monoxide generated, it acts on 50 per cent more ore, and under better conditions of efficiency, namely, lower temperature. The rate of increase of ore volume to coke volume is also approximately twice as great per hundredweight of coke decrease at 20-cwt. hot-blast consumption as at 28-cwt. cold-blast consumption. The coke saving in the two cases should, therefore, be very closely similar.

Iron Paint.

A paper by Mr. F. J. R. CARULLA on "artificial magnetic oxide of iron" refers back to the same author's former paper on a new iron paint invented by Dr. Wülffing (our Vol. V, page 395).

The chief points brought out in the present paper are:

Firstly, that to William Gregory, of Edinburgh, must be assigned the discovery of the artificial production of magnetic oxide of iron.

Secondly, that there are grounds for believing that magnetic oxide of iron made by the above process is either Fe_3O_4 or Fe_4O_5, and that any variation from these formulas is due to admixture of Fe_2O_3.

Thirdly, that to say whether the main portion of any sample is Fe_3O_4 or Fe_4O_5 is not a matter that can be asserted with certainty, although there are indications that two distinct bodies exist in different samples, one of these being most difficult of solution.

Fourthly, that notwithstanding those difficulties that all beginners are sure to encounter, the product is difficult to spoil in the making except as regards color, and the operator can

soon attain to the production of a commercially uniform article.

Finally, it may be added, that the protective character of this magnetic oxide of iron is most marked. Just as the Bower Barff coating and the film on Russian sheet iron, both magnetic, afford protection to iron surfaces, so does this product when laid on in the form of paint.

The action that takes place through the localization of scale on iron plates must not be thought to militate against the use of a magnetic iron paint. It might as well be argued that because a hot ember will burn a hole in the flesh, therefore, diffused warmth must also be harmful.

The great protective value of what one may be allowed to call the Gregory-Wülffing magnetic oxide of iron paint is acknowledged by all who have had any experience of it.

Corrosion of Iron.

Two papers on this subject were presented by Dr. J. NEWTON FRIEND.

The first paper, entitled "The Corrosion of Iron," is essentially a reply to some recent criticisms by Dr. W. H. Walker. Dr. Friend emphasizes that he is not an adherent of the "carbonic acid theory of corrosion," but rather of the general "acid theory of corrosion." He claims that "pure water, oxygen and iron may remain with one another for an indefinite period without the formation of rust. The presence of a trace of some acid to act as catalyser is absolutely essential if oxidation of the metal is to begin." He agrees that the acid theory is in harmony with the electrolytic theory of ionization.

Dr. Friend's second paper deals with "the action of air and steam on pure iron." The results of his experiments are summed up as follows:

1. Pure iron combines with ordinary air and with air dried over phosphorus pentoxide with increasing readiness as the temperature rises. Below 150° C. the oxidation proceeds too slowly to be readily detected.

2. When pure iron is heated in pure steam at temperatures ranging from 350° C. upward, the metal becomes tarnished.

3. The author concludes that the action of steam on iron takes place in two stages, comprising, first, the dissociation of the steam, and, second, the combination of the dissociated oxygen with the iron, and the consequent liberation of free hydrogen gas.

4. If conclusion 3 is correct, the dissociation pressure of the oxide of iron produced at 350° C. is of the order of 1.02×10^{-13} atmosphere.

Production of Iron and Steel in the Electric Furnace.

A paper by Mr. E. J. LJUNGBERG gives in the introduction some notes on steel making in the electric furnace in Sweden.

At Gysinge, one of the works belonging to the Stora Kopparbergs Bergslag, there is one Kjellin induction furnace with a capacity of 2 tons, but as this is working as a Talbot furnace, not more than about 1 ton at a time is tapped.

The power continuously used in this furnace represents about 200 kw, and the output in 300 days amounts to about 1200 tons of ingots, using 50 per cent pig and 50 per cent scrap. As no other pig iron is used except the famous Dannemora brand made by the firm, which, as everyone knows, is extremely low in phosphorus and sulphur, the process can hardly be called a refining process.

The product is a carbon steel of high quality, possessing some superiority over steel made by the ordinary melting processses; one special quality is that it is comparatively soft to work, either hot or cold, although high in carbon. It is a superior carbon tool steel.

It may be of interest to state that the company makes about 15,000 tons of Dannemora charcoal pig iron annually, of which about one-third is exported and two-thirds are used at the works at Soderfors and Elfkarleo for the manufacture of Dannemora Wallon bar iron, open-hearth and crucible steel.

The main part of Mr. Ljungberg's paper deals with the inter-

esting and extended experiments made at Domnarfvet with iron-ore reduction in the electric furnace. These were fully described in Dr. E. Haanel's paper and official report, published in our June issue, page 250, and October issue, page 420.

Carbon Tungsten Steels.

Mr. THOMAS SWINDEN's paper on the constitution of carbon-tungsten steels results in the following conclusions:

Hardness tests and exhaustive microscopic examination support in every respect the conclusions previously recorded upon the cooling curve work. Firstly, that the "lowering temperature" marks a definite reaction in which the tungsten is, involved; and, secondly, that the rate of cooling from above the lowering temperature is without the influence on the low point. Some facts are stated and observations made, suggesting that the hypothesis of Edwards, that the lowering of the point is due to the formation of the carbide of tungsten, is untenable.

The theory of a double carbide formation is also difficult to account with cooling curves and microscopic facts. A tentative hypothesis is given, wherein the lowering of the recalescence point it attributed to the solution of a tungsten compound, probably Fe_3W, at the lowering temperature. The tungstide is reprecipitated at the low point, and the Fe_3C immediately separates also.

Some figures in support of the latter view are included.

Economy of Rolling Mills.

Mr. C. A. ABLETT in his paper on "the determination of the economy of electrically driven reversing rolling mills' pointed out the advances made in recent years in this direction, which appears to be amply justified by the economy obtained in spite of the increased capital expenditure. At the present time, the question of saving in fuel consumption appeals to most steel makers as the chief inducement offered by electrical driving as the possibilities in the direction of greater output are not fully recognized, there being as yet no published figures relating to this. It is, therefore, of interest to consider the methods by which the economy in fuel, power or steam consumption can be ascertained.

Tests are frequently made to determine the economy of a reversing mill engine, either:

(1) By indicating the engine and estimating the steam consumption per indicated horse-power from some of the larger diagrams; or,

(2) Where boilers can be isolated, by measuring either the feed water or the coal burned for a considerable period, and keeping a record of the tonnage of steel rolled over that period, so that the result is expressed in pounds of coal or pounds of steam per ton rolled.

The author discusses critically these two methods, and explains his reasons for thinking that they have comparatively little value. The energy consumption of an electrically driven reversing rolling mill, as expressed in kw-hours per ton rolled, can be determined in the simplest possible manner by inserting an ordinary watt-hour meter in the supply system. If a reading of this instrument before the commencement of a shift and a second reading at the end of the shift are taken, the difference gives the total kw-hours used during the shift, and dividing this by the tonnage rolled, the total kw-hours per ton is obtained. Such readings can quite easily be taken for every shift, and a continuous check on the energy consumption can be kept.

Results expressed in kw-hours per ton are generally found most useful, as the cost of the kw-hour varies according to local conditions, and knowing this cost, the total cost of power can be arrived at directly. The efficiency of the electrical plant can also be checked in the simplest possible manner by placing a second integrating wattmeter in the armature circuit of the mill motor.

The records of this wattmeter will be less than those of the one placed in the supply circuit, the difference being the losses in the electrical plant. This does not take account of the

efficiency of the mill-motor armature, but as this is of the order of 97 per cent to 98 per cent, it can well be neglected. The following figures show some characteristic values for the kw-hours per ton rolled obtained from tests on reversing mills:

	kw-hours per ton.
4½" x 4½" billets from 2.5-ton ingots. Output 53 tons per hour....	22.5
6" x 6" blooms from 2.5-ton ingots. Output, 63 tons per hour........	17.5
8" x 8" blooms from 2.5-ton ingots. Output, 80 tons per hour........	13.0
12" x 9½" blooms from 7-ton ingots, measuring 34½" x 25". Output, 65 tons per hour	11.2
32" x 9" slabs from 6-ton ingots, measuring 36" x 19½". Output, 40 tons per hour	4.3
32" x 5" slabs from 6-ton ingots, measuring 36" x 19½". Output, 40 tons per hour	5.8
Flange rails, 100 lb. per yd. from 2-ton ingots. Output, 30 tons per hour	48.0
Beams, 120 lb. per yard, from 1.5-ton ingots......................	36.0
Channels, 92 lb. per yard, from 1.5-ton ingots....................	37.0

Tests of Cast Iron.

The very great variations in the tests which have been obtained from cast iron from time to time, and the differences of opinion which exist as to the best methods of testing, determined Mr. E. Adamson to make the comparative tests which form the subject-matter of his paper on tests of cast iron. These tests were all carried out in actual foundry practice. The chief results are as follows:

The best tensile and transverse tests are obtained from bars which have been machined, instead of bars tested as cast with the skin on.

Transverse test-bars cast on edge and tested with the "fin" in compression give the best results in testing.

The transverse test is not so reliable or helpful as that of the moment of resistance.

The use of high-grade ferro-silicon in the foundry is of no commercial value.

Cast iron gives the best results when poured as hot as possible.

The "Growth" of Cast Iron.

A paper by Prof. H. F. Rugan and Prof. H. C. H. Carpenter deals with the peculiar phenomenon of "the growth of cast irons after repeated heatings," which had first been studied by Mr. A. E. Outerbridge, Jr.

The present authors have made an extended investigation in which they determined the conditions under which the maximum growth of commercial cast irons is brought about by repeated heatings.

For growth to take place both heating and cooling are required. A given specimen grows no more under a 17 hours' than a three hours' treatment.

Three commercial cast irons were investigated. They grew at different rates and to different extents. After 94 heats they reached a constant volume. The growths varied between 35.21 per cent and 37.50 per cent. An increase in weight was found in all cases.

The authors solved the practical problem to find an alloy whose volume remains constant even after repeated heatings at about 900° C. Such an alloy is a white iron with about 3 per cent of carbon and only small quantities of other constituents, of which, for the purpose, silicon is the most important and should not exceed about 0.2 per cent to 0.3 per cent.

The growth of the cast iron is intimately connected with the presence of graphite and silicon. Gases also play an important part. In some cases the growth in air on heating is entirely due to oxidizing gases penetrating the interior, while in other cases gases originally dissolved in the iron contribute to some extent to the growth.

The authors finally apply their results to explain the mechanism of the growth of annealing ovens and other cast-iron vessels in ordinary practice. These ovens are grey irons. They contain graphite and silicon. They contain some dissolved gases, and they are exposed in practice to the direct action of flame gases. They consist of four main structural constituents, which may almost be considered as three.

1. A solid solution of iron silicide in iron and manganese.
2. Graphite.

3. Some combined carbon-pearlite.
4. Phosphide eutectic .

With repeated heating 3 tends to pass into 2. Only 1 and 2 will be considered.

After the first heating, gases have penetrated to a certain depth. The authors' view is that, although the gases penetrate to a certain depth during this period, possibly along slits existing between the graphite plates and the solid solution of silicide in iron, and through holes which exist here and there, yet they are not actually absorbed by the solid solution until the oven is cooling. During this absorption the oxides of carbon oxidize the iron silicide, in the first instance, at the boundaries of the crystals. This reaction is accompanied by growth and incipient disintegration. Minute cracks are formed. There may be a series of minute explosions, owing to the reaction between the dissolved hydrogen and the penetrating oxides of carbon. The mechanically weak graphite may be disintegrated and forced into holes originally existing in the metal. Nitrogen enters along with the oxides of carbon, and is absorbed to some extent. The net result is a slight growth of the oven by the time it has cooled to the ordinary temperature.

When the oven is next heated, the furnace gases penetrate a little farther, owing to the fresh avenues opened up by the reactions just described. On cooling these reactions are repeated, and in this way more of the iron is disintegrated and a further growth takes place. Simultaneously, if the iron is close-grained, hydrogen and nitrogen are liberated in the interior at the boundaries between the solid solution and the graphite. Their coefficient of expansion is so much greater than that of the solids that they exert a considerable pressure, with the result that the mechanically weak graphite is disintegrated, and appears to collect in the holes of the casting. Where the boundary between two holes consists of graphite, it is destroyed by this action, and the two holes become one.

As the heat progresses these changes continue. After each heat the external gases have penetrated a little farther. Finally, they work their way right through the oven, the rate depending on its chemical composition, physical texture, etc.

When this condition is reached the oven has grown to its full extent. Some of the graphite has been burned off, all the silicide of iron has been oxidized, probably to a mixture of iron oxide and silica, and some iron has been oxidized as well. The main cause of the growth is the disintegration of the material caused by the oxidation of the iron silicide. In close-grained irons the pressure of dissolved gases also contributes to the growth. At the conclusion of the process the structure has been revolutionized; the oven has lost the properties of cast iron. It has no mechanical strength, and can be sawn like a piece of chalk.

The authors have no hesitation in recommending that white irons should be tried for annealing ovens instead of grey. The most suitable composition appears to be an iron with about 3 per cent of carbon and as few impurities as possible. Of these silicon is the most important, and should not exceed 0.2 per cent to 0.3 per cent. This iron would probably shrink slightly on repeated heating. The reason why an upper limit of 3 per cent of carbon is suggested is that white iron higher in carbon will tend to deposit temper carbon. Where this is the case, the material will begin to grow. Even so, however, the growth will never be as much as in a grey iron. It is possible that an oven constructed of white iron may prove to be unsuitable, because it may crack on heating. Should this difficulty arise, it may perhaps be overcome by modifying the design.

Permanent Way of British Railways.

Mr. R. Price-Williams presented a paper on "the serviceable life and cost of renewals of permanent way of British railways." According to the Board of Trade Railway returns (1907), there are, roundly speaking, a little over 23,000 miles of railway open for traffic in the United Kingdom, of which about 13,500 miles consist of double and more lines and about 10.250 miles of single lines, besides which there are 14,000 miles of sidings.

The total annual cost of the maintenance and renewal of the permanent way and works amounted to roundly £11,000,000 sterling, nearly 15 per cent of the entire working expenses which have now and for some years past reached the exceptionally high figure of nearly two-thirds (63 per cent) of the entire railway gross receipts.

The average cost of renewals per mile varies from an average maximum of £418.18 per mile during the 10 years, in the case of the London, Brighton & South Coast Railway, to a minimum of £190.80 per mile in the case of the North British; while the tonnage of goods and minerals per mile in the latter case is just double that of the London, Brighton & South Coast.

Evidently, the tonnage of freight alone does not account for the exceptionally large cost of renewals of the permanent way of some of the prominent British railways; the principal additional factor is probably the greatly increased weight and speed of the passenger traffic which was made possible by the introduction of Bessemer steel rails in the early sixties of the last century. It is interesting to compare the cost of renewal of the iron rails before that date and of the steel rails afterward.

The total cost of the renewal of nine principal railways with iron rails during the 18½ years prior to 1865, with an average aggregate of 3401 miles of way during that period, only amounted to £5,796,135 and to an average of £170.40 per mile of way. It rapidly increased during the first 10 years after the first partial introduction of steel rails to £285.53 per mile, partly owing, no doubt, to the high price then of steel rails. Notwithstanding the great subsequent reduction in the price of steel rails to a lower figure than even the best iron rails, the expenditure in the renewal of way on these nine principal railways has, however, now reached an amount of £28,101,881 and £314.66 per mile of railway during the short space of the last 10 years—a fivefold increase in amount and now double the cost per mile in renewals—the mileage of these nine railways having increased from 3401 to 8930.

While the mileage during the last 47 years has only a little more than doubled, the working expenses have increased nearly sixfold; the number of pasengers carried has increased nearly sevenfold, the tonnage of goods and minerals carried has increased nearly fivefold, while the number of carriages and wagons has only increased three fold; no doubt a considerable portion of the increase of the permanent way expenses is mainly due, as already stated, to the very large increase in the weight and speed of the passenger traffic, and partly to the very large increase in the tonnage of goods and mineral traffic, and also in some degree to its somewhat increased speed.

That the much greater strength and durability of the high-class of steel material, of which Bessemer steel is the type, has largely contributed to the exceptionally rapid growth, not only of railway traffic in this country, but of its trade and commerce generally, there can be no question.

In the second part of the paper the author gives detailed data illustrated by diagrams of the cost of maintenance and renewals of the permanent way of 15 principal British railways in the last 10 years with an aggregate of 15,184 miles of railway. In the average 504 miles had been worn out per year and have been replaced in the most, if not all, cases with stronger and better materials, and as the traffic on these railways is still rapidly increasing, it may be estimated that at least that quantity of worn-out steel rails will have to be simultaneously renewed during a similar period in the future in Great Britain.

Notes on Electrochemistry and Metallurgy in Great Britain.

(*From Our Special Correspondent.*)
Iron and Steel Institute.

The autumn meeting of the Iron and Steel Institute was held at the Institution of Civil Engineers and extended over three days, instead of two, as formerly, for the reading and discussion of papers. Lord Airedale presided on the opening day, Sept. 28, and the president, Sir Hugh Bell, occupied the chair during the remainder of the proceedings. The Carnegie gold medal was presented to M. A. Portevin on the second day. Abstracts of the papers presented will be found elsewhere in this issue. The discussions, generally, were wanting in animation, and, owing to lack of time, some papers of considerable interest—e.g., "The Constitution of Carbon-Tungsten Steels," by Mr. T. Swinden—were simply taken as read.

The reading of Herr E. J. Ljunberg's paper on **"The Production of Iron and Steel by the Electric Smelting Process"** evoked from Mr. P. R. Cobb the remark that the author's statement that no advance had been made, for commercial purposes, in the use of the electric furnace for iron-ore reduction was not in accordance with the fact that contracts for the erection of three new electric furnaces at Sault Ste. Marie had just been placed. He asserted that the opinion of the Canadian iron and steel men was very favorable to the electric furnace. By the middle of next year these Canadian reduction furnaces, producing silicon pig iron, ought to be running, and valuable commercial data would be furnished from the results of their operation.

Lord Airedale pointed out that many available sources of water-power in England were neglected, and that relying so much on coal power was not favorable to progress with the electric furnace.

The discussion of Mr. C. A. Ablett's paper on **"The Determination of the Economy of Reversing Rolling Mills"** was opened by Mr. Andrew Lamberton, who contended that the author had not adduced proof of the claims put forward for economy. A statement of cost expressed in kw-hours was academical, and steel makers wanted cost put commercially in pounds, shillings and pence. He had personally gone into the question and worked out the cost of production of a ton of rails with a plant turning out 300 tons in 10 hours, and found that with steam power—allowing 10 per cent for interest and depreciation—the cost was 5d. per ton, while with electrical power—allowing 15 per cent for interest and depreciation—the cost was 8.8d. per ton.

Lord Airedale considered that the electrically driven rolling mill had advantages for intermittent working where power was derived from an outside source.

Mr. Alexander Siemens quoted the old saying, "those are most deaf who do not want to hear." There was no difficulty in converting kw-hours into cost in money; and lengthy experience in working a 1500-hp or 1600-hp generating plant at his own works gave an average of ¼d. per kw-hour. The allowance of 15 per cent was not justifiable with properly selected plant. Many persons did not recognize the fact that it was cheaper to run big motors than small ones; and he called to mind a case in which, when, on his recommendation, a motor was replaced by another twice its size, surprise was expressed that the big machine consumed only half as much current as the small one. Current depended on the load, not on size of motor. His plant was as good now as when put down 20 years ago because it was kept within its power. If, said the speaker, you are advised to put down a 10-hp motor, then put in a 15-hp machine instead.

Mr. Ablett replied that at the Rhenish Stahlwerke a saving of 1 shilling per ton had been effected on an output of 5000 tons per week, and the oil consumption had been reduced by one-fifth. As to depreciation, the Niagara Falls Power Company started a 5000-hp plant 14 years ago, and the only repairs that had been necessary were rewinding after 10 years' running, and manifestly 15 per cent was far too high an allowance.

The paper by Professors H. F. Rugan and H. C. H. Carpenter on **"The Growth of Cast Irons After Repeated Heatings"** having been read, Mr. J. E. Stead said the paper added much to our knowledge of the subject. It had long been known that white iron did not grow so rapidly as grey iron, and white iron—furnace bars, for example—repeatedly

heated and cooled did not oxidize so rapidly as grey iron. Oxidation of grey iron followed along the graphite plates, which with every successive heating became more and more separated from the metal and thus permitted the passage of oxygen. As white iron contained no graphite, oxidation from such cause could not occur. He considered that with a greater percentage of combined carbon the oxidation would be less.

Professor Turner remarked that some years ago he had noticed much growth in the grids of muffle furnaces. He felt sure that the methods adopted by the authors were worthy of Dr. Carpenter's name. Whenever a constituent of an iron alloy separates out there is always an increase in the volume. He quite agreed that so long as iron remained white there would not be any expansion, but as soon as graphite is deposited expansion commences. In the growth oxidation occurs, and then we had ferric oxide and silica side by side. It was possible thus to obtain pure silica from silicon. He was inclined to regard the expansion as analogous to that of lead roofing on a sloping surface. If we imagined the iron to be in a soft state surrounded by a hard oxidized skin, it would be apparent that the iron would expand when heated, but could not contract to any great extent on cooling.

Mr. Saniter was interested more particularly with steel. He wished to point out that the sample referred to in Table 8 did not increase or decrease to any extent with repeated heatings. Rolled steel shortens as the result of repeated heatings in consequence of the elongated grain produced by rolling, returning to a shorter, rounded shape. The point which required explanation was: Why did alternate heatings and coolings cause growth? He thought that each consequent separation of impurities in crystalline form on cooling each time prevented contraction.

Dr. Rosenhain had found that in the case of white iron there was no growth until after separation of graphite had occurred. He thought that it would be very instructive to ascertain the rate of deterioration of the mechanical properties of iron as growth progressed.

The papers by Mr. Greville Jones on **"Uniform Moisture in Blast"** and by Mr. R. S. Moore on **"The Fuel Economy of Dry Blast as indicated by Calculations from Empirical Data"** were discussed together.

Mr. Martin said he had experienced a very great saving in coke by the use of the Gayley dry-blast system. He desired to state that his results had not been obtained in the blast furnaces only.

Mr. J. Harrison considered that further experiments were desirable to shed more light on the subject. Moisture could be reduced from 4 grains per cubic foot to 2 or 2¼ grains by cooling by means of ordinary water, and the reduction effected considerable economy.

Mr. Reece remarked that Mr. Moore's experiments seemed to prove what he has disproved. Increase of moisture was unquestionably prejudicial, and he asked whether benefit did not arise from mere uniformity. An experiment quoted showed results equally good with an increase of moisture as when its amount was smaller. At South Chicago twice as much moisture was removed as at Cardiff, yet results at Cardiff were as good. Therefore, what else but uniformity produced equally good results?

Mr. Foster wished to ask how the total calories given on page 8 of Mr. Jones' paper were arrived at.

Mr. Sterne vouched for the accuracy of the figures relating to dry-air blast. The resulting economy would recoup the cost of the dry-air blast plant in from 18 to 24 months.

Mr. Rogerson asked why the Steel Corporation used only one furnace with the dry-air blast.

Mr. Reece replied that they had three, and were putting down three more.

Sir Hugh Bell said he had once been told by a friend that it took £10,000 and 10 years to make a chemical experiment. He wished that all experiments demanded no greater expenditure of time and money. The final solution of the questions raised was not yet arrived at; and Mr. Reece's observations pointed to the desirability of further investigation. Yet reports from South Wales and elsewhere showed considerable economy resulting from the dry-air blast.

Mr. F. J. R. Carulla's paper on **"Artificial Magnetic Oxide of Iron"** was then read.

Professor Turner said that oxide of iron might still be magnetic, although varying from the formula Fe_3O_4. He had found by experiment that the proportions of ferrous and ferric salt could be varied considerably and yet the oxide obtained would be magnetic. He had had for analysis a sample of what was really magnetite, but the proportion of ferrous oxide was very small.

Dr. J. N. Friend's paper on **"The Corrosion of Iron"** followed, but there was not any discussion thereon.

The president remarked that whether the electrolytic theory or the acid theory were correct—and it was not improbable that both actions went on—the question of corrosion had become of supreme importance now that iron and steel were being used in large and increasing quantities for building construction. The attainment of the fullest possible knowledge of the subject was requisite, and any contribution to that end was valuable.

The papers read on the concluding day were those by Mr. R. Price-Williams on **"The Serviceable Life and Cost of Renewals of Permanent Way of British Railways,"** and by Mr. E. Adamson on **"Tests of Cast Iron."**

The discussion on the former of these was prolonged, but yielded but little of metallurgical interest, and related chiefly to comparisons of cost, weight of vehicles, etc., now and in 1860.

Mr. T. Hurry Riches said Mr. Williams had not made much allusion to quality of steel or sections of tires now and years ago. The tire section had a decided influence on the life of the rail. There was, fortunately, now more co-ordination between permanent way engineers and rolling stock engineers to adapt rails and tire sections to each other; and he hoped that the author's paper would tend to effect further improvement in this direction.

The president, in the course of his remarks, said the material, form and nature of running of tires had become matters of constant criticism. Rail makers had to be subject to various tests, and often had demands for contradictory qualities. He had taken a prominent part in producing rails of special hardness necessitated by modern brakes. The questions raised by the author were of vital importance to the country at large.

Prof. H. Lewin hoped that curves of circular radius would be replaced by the paraboloid form.

Speaking on Mr. Adamson's paper, Professor Turner asserted that rectangular test bars gave irregular results, and the utmost care was necessary to get a straight pull. Bars with the skin on gave high results, but were not so trustworthy as machined pieces. If test pieces were cast with the fin downward, higher figures were obtained. With regard to ferrosilicon, he had not advocated its use nor found it really advantageous, although it appeared that good results had been got by its addition just before pouring. If added at the right time and in the right amount, then well and good; if not, it were best left out.

Mr. Adamson replied that he believed higher results were obtained from machined bars, and that many results from unmachined bars might be termed "flukes." His experience was that only 20 per cent of the ferro-silicon used found its way into the iron. It was a very expensive addition.

The president characterised a "fluke" as something which we could not explain. He hoped that the author would soon be able to tell us there were no flukes.

The Separation of New Radio-Active Disintegration Products.

Dr. Otto Hahn, in his paper read before Section A of the British Association, at Winnipeg, remarked that Rutherford and Soddy's disintegration theory had resulted in the recogni-

tion of a considerable number of radio-active products, differing in chemical and physical properties, and separable by appropriate methods. Some emit A particles, some emit B particles, some emit both, and others appear not to emit any particles. The speed at which the A particles are emitted for any particular product is definite and characteristic for that product; but this does not appear to be the case with B rays, the absorption curves for which are complex in some cases and indicate B rays of a complex nature, while in other cases they show only rays of one type. Two years ago the author and Dr. Lise Heitner undertook a comparison of all the various B ray products under identical conditions, and they have now advanced the hypothesis that radio-active products consisting of a single substance emit radiation of one type only—either homogeneous A particles or homogeneous B particles. If this be true, then all substances emitting both A and B rays or complex B rays are of diverse composition and may be separated into at least two constituents. The active deposit of thorium was found to be composed of four different substances, the fourth of which had not previously been recognized, and emitted B rays hitherto attributed to thorium C. Similarly, the radio-active deposit of actinium contains three constituents, of which the third emits B rays previously considered as proceeding from actinium B. Thorium D has a life period of three minutes, and actinium C has a life period of 5.1 minutes.

In the case of radium there appear to be single B rays from the B substance and complex rays from radium C, which latter is, hence, probably of complex constitution and has three constituents, one A and two B ray substances. The "recoil method" of separation of the radio-active disintegration products was resorted to. Radium C yielded feeble results. If the A rays be emitted from the last product of radium C, then this probably consists of three products, one enduring 19 minutes, one with a period of one to two minutes, and the third having a very short life. Recent experiments appear to indicate that radium itself consists of two different substances, the second of which may be provisionally designated radium x and emits the familiar A particles, while the pure radium only gives out B rays, which are absorbed with facility.

LONDON, September, 1909.

SYNOPSIS OF PERIODICAL LITERATURE.

Copper.

Corrosion of Copper and Brass.—At the recent Manchester meeting of the (Brit.) Institute of Metals, Mr. E. L. Rhead discussed some causes of the corrosion of copper and brass. Copper and copper-zinc alloys in contact with saline solutions such as sea water corrode in a peculiar manner. Brass condenser tubes exhibit deep pits on the side next the water. These often occur in lines. In other situations and under other conditions copper enrichment takes place. The pits in the case of condenser tubes are commonest on the side of the tube lying undermost when the tube is in position. This corrosion is most erratic. It is generally attributed to selective chemical action, and to electrolytic effects due to the duplex structure of the alloy. In the experiments mentioned in the paper samples of hard copper and brass were submitted to corrosion in various saline solutions and their behavior noted. Some of the solutions were saturated with carbonic acid gas. The figures obtained showed the greater tendency of the hard material to corrode. The edges and parts of brass plates that were scratched showed deposition of copper. Strips of hard brass were softened at one end and bent into U shape. When the free ends were put into corroding solutions the hard limb dissolved more extensively and rapidly than the soft limb, the hard metal appearing to form an electric couple with the soft metal. Corrosion occurred in lines parallel with the direction of rolling. The surface of the hard metal was made very

rough and irregular. That of the soft metal remained smooth. These roughnesses may form points from which the disengagement of gases dissolved in water flowing through condenser tubes may take place, thus facilitating the pitting and hastening the corrosion and failure of the tube. From this it would appear that the final cold drawing of a tube to produce stiffness is liable to produce irregularities that may increase the rapidity of attack. (From advance sheets.)

Zinc.

Pure Spelter.—At the recent Manchester meeting of the (Brit.) Institute of Metals, Mr. John S. G. Primrose presented a paper on the production of pure spelter. After briefly reviewing the important commercial position of zinc and the existing methods of refining the metal, Mr. Primrose discussed the theory of the new process of purification by fume filtration during distillation. Lead is sensibly volatile below its boiling point in presence of zinc vapor and passes out of the retorts in a state of gaseous solution in the zinc, and the repeated infringement on the surface of the filter material dissociates the alloy, allowing the zinc to pass on to the condenser almost pure, but retaining the lead chiefly in the metallic condition and recoverable in this state. He shortly described the plant at Irvine Spelter Works and detailed the working of dross refining, which yields 99.8 per cent spelter from very impure material in one step.

The chief item of the paper was the description of recent experiments on the direct smelting of Broken Hill middlings, which gave most remarkable results and showed clear indication of a solution of the long-standing problem. The process is admirably suited for the commercial production of the highest grade spelter from this class of material, and although the tests were carried out in large furnaces of six or seven tons daily capacity, there is no reason why it should not be applied to furnaces of any existing capacity. It is most creditable that in the second run of only three days, two-thirds of the output was of 99.5 per cent purity and the remainder averaged 99.1 per cent zinc, particularly with over 13 per cent of lead in the middlings. The zinc smelting loss sustained on the average for the three days working in September was only 10 units, which is less than in ordinary practice, and that in spite of the fact that hand-made retorts were used. With denser machine-made muffles the loss should show a decided decrease. Of the lead in the middlings over three-fourths was retained in the residues as metallics, which further held 95 per cent of the total silver content of the charge. Quite 10 per cent of the lead was recovered from the filters in the metallic condition, and assayed 10 oz. of silver per ton. Besides these enormous advances in working, the process possesses the further advantages of being extremely simple, since the filter is a purely mechanical contrivance fixed between the retort and the condenser and not disturbed during the day's maneuvre. It has a wide range of usefulness and is easily adaptable to any class of material used, particularly if it is impure, and the extra cost of production amounts only to a few pence per ton of spelter. (From advance sheets.)

Alloys.

Aluminium-Copper-Tin Alloys.—These ternary alloys were the subject of a paper by C. A. Edwards and J. H. Andrew, read at the recent Manchester meeting of the (Brit.) Institute of Metals. Many of the industrial non-ferrous alloys contain more than two metals. These mixtures have been arrived at by the method of trial and failure, and, as a consequence, possess in a more or less degree the required properties for their particular purpose. This method of working was the only one available up to a comparatively recent date. But now, with the aid of the microscope and pyrometer, the constitution of alloys can be determined, and from such data the properties and correct heat-treatment deduced.

Very little is known of the constitution of alloys containing

more than two elements, therefore, it cannot be said that the ternary alloys in use are the best possible mixtures of their components.

The conclusions arrived at by the authors were as follows:

No ternary compound is deposited from the liquid alloys.

No ternary eutectic is formed.

Judging from the constitution and appearance of the alloys it is clear that those possessing reasonable mechanical properties are confined to two very limited areas, viz: those containing upward of 86 per cent of copper, and those which contain more than 85 per cent of aluminium.

Viewed from a theoretical standpoint no advantage is to be gained by adding tin to those alloys containing about 10 per cent of aluminium and 90 per cent of copper.

The authors think it probable that an alloy containing about 6.5 per cent aluminium, 5.5 per cent of tin and 88 per cent copper will have the same properties as an alloy containing 10 per cent of tin and 90 per cent of copper. Such a ternary alloy would be cheaper than the copper-tin, and would have a lower specific gravity.

Alloys containing the compound CuAl₂ with tin may be found of use as bearing metals, for when made under certain conditions they consist of a very hard constituent embedded in a soft matrix of tin. (From advance sheets.)

Miscellaneous.

Specific Heats of Silicates and Platinum.—In the *American Journal of Science* for October, W. P. White gives an account of a new determination of specific heats of silicates and platinum. For determining the specific heats of silicates up to 1500° C., the method of mixtures, in which the heated substance and containing crucible are dropped from a furnace into a calorimeter at room temperature, was selected as the most accurate.

All measured temperatures, including that of the calorimeter, were read by thermo-elements. By this means rapidity and simplicity of manipulation were secured. A consideration of the various sources of error indicates for the mean specific heats a final accuracy of better than 0.5 per cent at most temperatures. The true specific heats, derived from these, are less accurate.

The chief numerical results are given in the following two tables:

TABLE I.

Mean specific heats from zero, of platinum, pseudo-wollastonite, wollastonite, orthclase, diopside, quartz, orthoclase glass, and a soft tubing glass.

Upper temperature.	Pt.	P. Woll.	Woll.	Or.	Di.	Qu.	Or. glass.	Soft glass.
100°	....	.....	.1833	.....	.1919	.1840	.....	.1977
	....	.....	.1813	.....	.1905	.1851	.....	.1974
	....	.....	.....	.....	.1920	.....	.....	.....
500	.03348	.2159	(.2180)	.2248	.2310	.2372	.2291	.24000
	.03355	.2169	.2169	.2246	.2308	.2368	.2304	.24077
	....	.....	.2168	.....	.....	.....	.....	.24137
	....	.....	.....	.....	.....	.....	.....	.24104
700	.03423	.....	.2286	.....	.2420	(.2547)*	.....	.2646
	.03428	.....	.2289	.....	.2422	.2559*	.....	.2639
	....	.....	.....	.....	.....	.2556*	.....	.....
800	....	.....	.....	.2401	.....	.....	.2465	.....
	....	.....	.....	.2402	.....	.....	.2473	.....
900	.03515	.....	.2354	.....	.2400	.2597*	.....	.2791
	.03514	.....	.2355	.....	.2488	.2594*	.....	.2796
	....	.....	.....	.....	.2483	.....	.....	.....
1100	.03573	.2380	(.2423)	.2505	.2562	.2643*	.2588	.2907
	.03578	.2380	.2404	.2505	.2562	.2643*	.2588	.2907
	......	.2375	.2404	.2513	.2564	.2646*	.2591	.2909
	....	.....	.2403	.....	.....	.....	.....	.....
1300	.03640	.2422	.....	.....	(.2613)	.....	.....	.2945
	.03647	.2416	.....	.....	.2596	.....	.....	.2949
	....	.....	.....	.....	.2601	.....	.....	.2972
	....	.....	.....	.....	.....	.....	.....	(.2996)
1500	.03675	.....	.....	.....	.....	.....	.....	.2999
	.03682	.....	.....	.....	.....	.....	.....	.2998
	....	.....	.....	.....	.....	.....	.....	.3024

*Affected by the inversion at 575°. † Heated by lead bath.

TABLE II.

True specific heats of substances given in the preceding table except quartz.

Temperature.	Pt.	Woll.	P. Woll.	Or.	Di.	Or. glass.	Soft glass.
500°	.0356	.251	.250	.257	.262	.264	.298
700	.0368	.263	....?	.272	....	...	.324
800	.....	....	....	.272	....	.282	....
900	.0380	.262	....	....	.281	....	.340
1100	.0390	.261	.259	.279	.286	.297	.335
1300	.0400	....	.257	....	.278	...?	.333
1500	.0407	....	....	....	....	....	.332

RECENT METALLURGICAL AND ELECTRO-CHEMICAL PATENTS

Electrochemistry.

Electric Furnaces.—It is a well-known fact that the efficiency of an electric furnace can be increased by heating the outside walls, because the heat loss through the walls is thereby reduced on account of the reduced temperature drop in the walls. Mr. W. Acheson Smith, of Niagara Falls, N. Y. (International Acheson Graphite Company), makes use of this principle in a simple way in such cases where combustible gases are given off from the charge, such as carbon monoxide, hydrogen, hydrocarbon vapors, etc. Such gases are given off, for instance, from the charge in carborundum or graphite furnaces. Mr. Smith makes the walls permeable by providing channels in the same through which the vapors may escape. Provision is made to concentrate the heat obtained from the
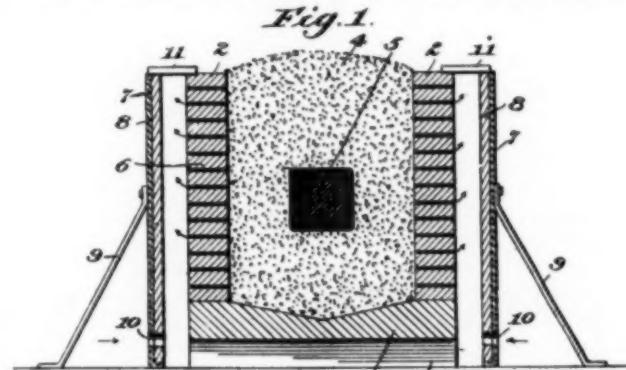

FIG. 1.—REDUCTION OF HEAT LOSS FROM ELECTRIC FURNACE

burning gases in next proximity to the walls. In Fig. 1 this is done by means of the heat-retaining walls 7 spaced from the permeable walls 2. These heat-retaining walls 7 are of sheet metal with an interior lining of a material of low-heat conductivity 8. Air in excess is admitted to the space between the permeable walls 2 and the heat-retaining walls 7. Modifications of this construction are also described. The effect of this construction is a double one. Since the rate of flow of heat from the charge through the walls is reduced, a considerable economy of energy consumption is effected in maintaining any given temperature or range of temperature in the charge. Secondly, in the production of materials requiring more or less definite temperature conditions, as, for instance, carborundum, the productive zone of the furnace is greatly extended. The result is therefore not only increased economy of energy consumption, but increased output in pounds. (935,937, Oct. 5, 1909.)

Carborundum.—While in the classical Acheson process of manufacture of carborundum a resistance furnace is used, Mr. F. J. Tone (Carborundum Company) has found that an arc furnace has certain advantages if it is desired to produce carborundum of a dense compact variety with great toughness. The charge surrounds the electrodes, the arrangement being otherwise the same as in another. When the arcs are started in the usual way, that part of the charge within the arc zone and below the electrodes is converted into silicon carbide, and by raising the electrodes from time to time the finished product builds up to any desired height. Fresh mixture is added around the electrodes from time to time as the charge under treatment is converted into silicon carbide. If it is desired to run the furnace continuously, the finished product may be withdrawn from the column which has built up under the electrodes at the farthest point from the arc zone continuously or intermittently, without shutting down the furnace or disturbing the mass in the vicinity of the reaction zone. One of the advantages of this method is that when the charging mixture contains constituents which make it more or less conductive, such as coke or sand

having high percentages of impurities, or when the mixture contains "white stuff" (which term is applied to the partially converted mixture of a silicon carbide furnace which has already been used in the process), the area of the reaction zone is thereby increased and rendered more efficient. (937,119, Oct. 19, 1909.)

Silicon.—In certain electric furnace processes it is important to remove as quickly as possible the products of reaction from the reduction zone. This is, for instance, the case in the production of silicon and silicon alloys. F. J. Tone carries out such a process in an electric furnace, as shown in Fig. 2. The hearth 2 of the furnace is formed of carbon or graphite, while the side walls 4 are of a non-conducting refractory material. The charge rests upon a hearth 8 which ex-
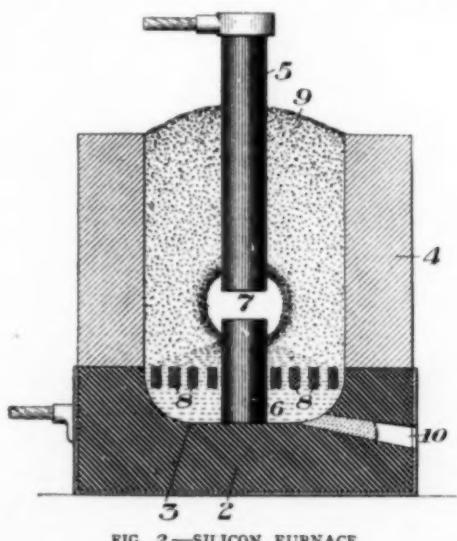
FIG. 2.—SILICON FURNACE.

tends over the collecting receptacle within the terminal 2 and in the form shown is composed of horizontally extending carbon bars, which are suitably supported in or on the side walls. These bars are spaced apart a proper distance to allow the molten products to drop between the hearth so formed, while this hearth supports the charge and is practically impervious thereto. The charge is indicated at 9, and fills the space around the upper electrode. The intermediate hearth is placed between the reduction zone of the arc and the receiving space at the base, and is sufficiently elevated above the base to give a receptacle of the desired size. From this receptacle the product may be tapped out through the taphole 10. In the operation of the furnace, the charge is supported upon the hearth through which the products drop from the reduction zone into the receiving space. The products are thus not liable to be contaminated by the charge, which is kept apart by the hearth which supports it. (937,120, Oct. 18, 1909.)

Magnesium.—F. von Kügelgen and G. O. Seward (Virginia Laboratory Company) who have done considerable work in the past on the electrolytic production of magnesium, chromium, etc., have patented a new process for the production of pure magnesium. It consists of two steps which are carried out in two different vessels. The first step produces an alloy of magnesium with a less electro-positive metal (aluminium) by electrolyzing a molten magnesium electrolyte with an insoluble anode and a cathode of a molten metal less electro-positive than magnesium (like aluminium). The second step produces pure magnesium by consecutive dissolution and deposition from such alloy, the latter being used as the anode in a suitable electrolyte. In the first step any less electro-positive metals than magnesium, which may be present as impurities in the initial electrolyte, are separated together with the magnesium and are absorbed by the molten alloy of the cathode. In the second

step these impurities, being less electro-positive than magnesium, are not dissolved therewith, but remain in the molten anode, pure magnesium being thus produced. In the first step an electrolyte of low specific gravity is used so that an alloy very rich in magnesium can be produced without danger of its leaving its position at the bottom of the electrolytic vessel. In the second step an electrolyte is used of sufficiently high specific gravity to insure the rapid flotation of the magnesium to the surface as soon as deposited and its collection there. Molten aluminium forms the cathode in the first step and a molten alloy of aluminium and magnesium the anode in the second step. The molten electrolyte in the first step is preferably $MgCl_2 + KCl$ with carbon anodes and a cathode of molten aluminium. The magnesium produced at the cathode alloys with the aluminium. As the electrolysis proceeds the alloy becomes richer in magnesium; when it contains from 50 to 60 per cent of magnesium, it is removed either in whole or in part and is used as the anode in the second step of the process. The electrolyte in the second step may be similar to that in the first step excepting that a certain proportion of a heavy salt of a more electro-positive metal than magnesium (e.g., barium-chloride) is added to increase the specific gravity and to facilitate the flotation of the magnesium. As magnesium is dissolved from the anode to the same extent as it is deposited at the cathode, the electrolyte in the second step of the process remains substantially unchanged. Magnesium, being the most electro-positive constituent of the molten anode in the second step of the process, is alone dissolved and redeposited, care being taken to avoid exhausting the anode too much of its magnesium content. For this purpose a large part of the magnesium which forms the cathode in the second step is removed from time to time and most of the nearly exhausted alloy of the anode is tapped and replaced by a rich alloy from the first step. (935,796, Oct. 5, 1909.)

Diaphragm for Electrolytic Cell.—A practically non-conducting carbonaceous diaphragm is made by Mr. I. L. Roberts as follows: The diaphragm is first cut into the desired form from wood, or molded into the desired form from wood pulp, etc. It is then placed in a suitable oven and heated very slowly, keeping the temperature as nearly as possible uniform throughout all parts of the vessel. The heating should be carried only to such a degree that the diaphragm will be charred without becoming conductive to any appreciable extent. If the diaphragm is made from wood of a good quality that is of even grain, free from cracks, etc., it will retain its form very closely. If it is to be in the form of a flat plate or sheet and is made from wood pulp, etc., it must be prevented from warping or twisting in the process of carbonization, and for this purpose it is clamped between a pair of iron plates during the baking, perforations being provided in the clamping plates to permit escape of the gases due to decomposition. If the heating is not carried too far, the conductivity of the diaphragm will be sufficiently poor to prevent its action as a bipolar electrode used in the electrolytic cell. (936,439, Oct. 5, 1909.)

Iron and Steel.

Electric Steel Refining.—Mr. O. Thallner, who has had an extended experience with the Héroult steel furnace in Bismarckhütte, Germany, patents the following process of producing steel free from oxides. The application of silicon for the deoxidation of steel and slag is well known. In deoxidizing steel ferro-silicon is added to the molten metal before or during tapping. In both cases the silicon effects deoxidation by reducing the protoxides of iron or manganese present. The silicon is not only used up in this action, but there remains also a considerable quantity of the products of the reduction, for instance, silicic acid in such a fine state of division emulsified in the metal, that it is not capable of separating out in the short time before pouring. The result is that only a small quantity of the pure silicon remains in solution in the steel and as this small quantity only acts for a short time it has

practically no influence on the internal structure of the steel. On the contrary, the fine emulsified silicic acid has a disadvantageous action on the internal structure. If it is desired to cause the silicon to act advantageously on the internal structure the metal must contain a greater quantity of the silicon and be subjected to the protracted action of the silicon at the melting temperature.

It is known that in the Martin furnace a strong blowing action is obtained in consequence of the gases of combustion. That is to say, there is a constant excess of oxygen present in the slag, and this oxygen has a constant blowing action on the metal bath below it. It is, therefore, impossible to obtain a constant percentage of carbon in the metal in a basic-lined furnace of this kind as the carbon is in contact with the slag which is rich in oxygen and is subjected to constant changes, as also is the manganese in the metal bath. This oxygen, of course, also affects the silicon, as the silicon has a great affinity for the oxygen in the slag, and passes over the slag as silicic acid. It appears, therefore, to be impossible to retain pure silicon dissolved with a basic-lined Martin furnace and it appears also impossible to obtain a favorable action of the silicon on the internal structure of the steel.

There still remains the possibility of adding the silicon before tapping or in the ladle. Silicon, of course, always reduces the protoxide of iron and manganese out of the slag in a Martin furnace. The object aimed at, however, was difficult to obtain, as the metal below the slag might still remain rich in oxygen and in addition very large quantities of silicon were necessary to bring about the permanent silicizing, as the slag constantly took up oxygen from the combustion gases and this oxygen had to be continuously removed. The slag was, therefore, always more acid in its nature and increased in its tendency to give up oxygen to the metal bath. It may be, therefore, assumed as a practical impossibility to melt metal in a basic flame-heated furnace, and still retain a reasonable proportion of silicon in solution.

Mr. Thallner discovered that the protoxides may be removed and pure silicon taken up in solution by the steel by treating blown steel in an electric furnace with a basic lining and heating the steel together with silicon in said furnace. The electric furnace with a basic lining in consequence of the high temperatures obtained retains the slag in a much more basic character than was at all possible in a Martin furnace. The consequence is that the slag is less liable to take up oxygen from the air as there is no oxidizing flame present in the electric furnace. The proof of this may be found in the fact that the metal may be heated for several hours in an electric furnace with a basic lining without altering the percentage of carbon and manganese in the metal. The proof is also to be seen in that the slag may be retained free from iron for several hours. This circumstance alone permits the carrying out of the following process.

The Martin steel or the melted product from any other blowing apparatus is passed into a basic electric furnace. Sufficient ferro-silicon is added, either in the electric furnace or when tapping into the ladle, to completely deoxidize the metal so that a fixed amount of pure silicon remains in solution. When added in the electric furnace the ferro-silicon may be laid in the furnace and the metal poured thereon or the ferro-silicon may be thrown on the top of the metal bath before the lime is added for forming the slag. The chemical action which results is as follows: The product of the deoxidation which is emulsified in the metal has time during the melting in the electric furnace to separate out and this product passes in the form of silicic acid into the slag. The pure silicon held in solution is neutral as regards the basic lining. In consequence the basic lining of the furnace is not attacked, whereas the excessive addition of silicon on a basic Martin furnace led to the formation of large quantitiees of silicic acid which attacked the lining of the furnace very severely. If the slag in the electric furnace still contains iron-protoxide, the iron in the slag is gradually extracted by means of the silicon in the

bath, and this reduction takes place at the contact surface between the slag and the metal bath. The reduction further takes place until the whole content of silica has been used up or until the slag is free of iron. In order to retard the loss of silicon it is necessary to accelerate the deoxidation of the slag. This may be effected by throwing on charcoal or the like, or aluminium compounds, or even pulverized ferro-silicon. When the deoxidation is complete in the slag, it becomes white or falls to a powder when exposed to the cooling action of the air. When the slag becomes white or falls to a powder in the air, the metal bath below the slag may be assumed as in a proper state for taking up pure silicon, and that the silicon remaining in solution in the metal will no longer be used up. In consequence, if further additions of ferro-silicon are made, the silicon acts on the internal structure of the metal so that the resulting product is just as fine in grain and as tough as if the metal had been treated in an acid-lined electric furnace or in a crucible. This is really the novel technical effect obtained by the invention, viz., to bring about the permanent action of the pure dissolved silicon on the internal structure of the steel in a basic-lined furnace. (937,486, Oct. 19, 1909.)

Copper.

Brass and Bronzes.—To produce alloys of copper with tin, zinc, lead, etc., Mr. A. J. Rossi, the pioneer of the titanium industry (Titanium Alloy Manufacturing Company), proposes to alloy the copper not with pure tin, zinc or lead, but with alloys of these metals with titanium. The titanium has a purifying effect and enables sound castings to be made, since the formation of blow holes, due to gases, is avoided. To make, for instance, an alloy of titanium with tin, he mixes tin with tin oxide, titanic acid and aluminium shots together and heats them in an electric furnace. This causes the following two reactions:

$$3SnO_2 + Al_4 = 2 (Al_2O_3) + 3Sn$$
$$3TiO_2 + Al_4 = 2 (Al_2O_3) + 3Ti$$
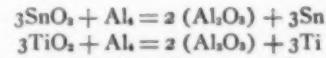
A fusible slag such as broken glass or a mixture of glass with iron blast furnace slag is useful as a protection of the molten bath. Such a protection is necessary in the manufacture of the zinc-titanium alloy. In the same way alloys of titanium with lead or with manganese can be made. (935,863, Oct. 5, 1909.)

Alloys.

Substitutes for Platinum.—As a substitute for platinum for electrical contacts E. B. Craft and J. W. Harris (Western Electric Company) have patented an alloy having the following composition: Gold, $67\frac{1}{2}$ per cent to 70 per cent; silver, 25 per cent; platinum, 5 per cent to $7\frac{1}{2}$ per cent. A second patent refers to another alloy of the same composition as the one just described with the exception that 5 per cent to $7\frac{1}{2}$ per cent of nickel are substituted for the platinum. Both alloys are claimed to have all of the characteristics peculiar to platinum, to be considerably cheaper and somewhat harder. (937,284 and 937,285, Oct. 19, 1909.)

Wood Pipe.

The question of securing satisfactory piping for the large quantities of water under pressure often required by mining operations or for hydroelectric power development in rugged portions of the West is one of considerable importance. Large-size cast-iron pipe is with difficulty transported and laid in inaccessible regions, and wrought-iron and steel pipe has often been resorted to.

The National Wood Pipe Company, of Portland, Ore., San Francisco, Cal., etc., is manufacturing pipe of redwood or fir staves which they recommend for this and similar classes of work. "Machine banded pipe" is made in sections up to 20 ft. in length, of diameters from 2 in. to 24 in., and for pressures up to 400-ft. head. The banding consists of heavily galvanized steel-wire, which after winding, is coated with hot asphaltum and tar. Cast-iron, wood or steel collars are used

to connect sections. This makes a satisfactory pipe for water works, mines, hydraulic dredges, electric conduits and steam-pipe covering.

"Continuous stave pipe" is made in larger sizes, from 10 in. to 12 ft. diameter, and from 100 ft. to 100 miles in one length, and is constructed to withstand pressures ranging from 20-ft. to 300-ft. head. It is, of course, built continuous, and in place, all staves, bands and other material being delivered to the pipe line in knock-down form. The ends of the staves are connected by a tongue which prevents butt-joint leakage and the pipe is banded with individual threaded round-steel rods, held in place by malleable or cast-steel shoes.

Among the advantages claimed by the manufacturers are that this pipe is not rusted or corroded by water, minerals, acids or fumes, does not taint fluids flowing through it, is not easily burst by freezing, requires less experience and labor to lay, is cheaper than iron or steel, and more durable than either thin steel or wrought-iron pipe.

FIG. 2.—INDICATOR DIAGRAM WITH EQUALIZATION OF PRESSURE.

High Vacuum Air Pumps.

Some years ago chemical works were satisfied with an average vacuum of about 2.75 in. of mercury absolute pressure for evaporating and similar purposes. It has now been realized that great advantages can be obtained by using the highest possible vacuum. Among these might be mentioned the following:

1. To greatly increase the efficiency of existing evaporating or distilling plants without any alterations to the apparatus.

2. To evaporate liquids at ordinary temperatures which otherwise could only be evaporated by means of hot steam.

3. To distill fluids which could not be evaporated in a low-vacuum plant, because of the damage done at the higher temperature corresponding to the low vacuum.

4. To evaporate very quickly by means of a high vacuum such fluids which possess a high boiling point.

The above advantages can easily be accounted for when we remember that the higher the vacuum the lower is the equivalent
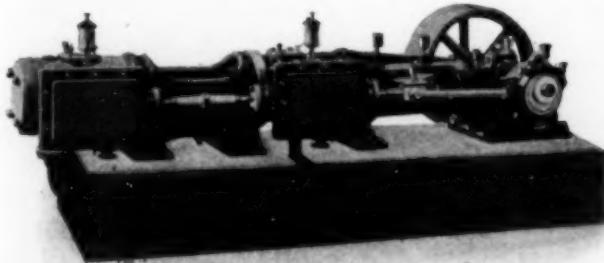

FIG. I.—HIGH-VACUUM PUMP.

evaporating temperature—that is, the well-known curve giving the relation between pressure and evaporating temperature changes rapidly as the point of absolute vacuum is approached and we then get a more rapid decrease in evaporating temperature for a slight increase in vacuum than when working at lower vacua. The firm of Klein, Schanzlin & Becker, of Frankenthal, Pfalz, Germany, are manufacturing a line of dry-vacuum pumps with an improved system for pressure equalization (Burckhardt & Weiss), which is designed to take advantage of these possibilities.

The slide valve has been adopted and with a view to obtaining the highest volumetric efficiency the valve is fitted with trick passage, which places both sides of the piston in communication at the end of the stroke and thus practically neutralizes the effects of clearance. The accompanying indicator cards (Figs. 2 and 3) show the effect of this device.

By thus equalizing the pressure at the end of the stroke, the full suction effect is obtained early, and, as shown here, about 93 per cent of the stroke is utilized for suction as compared with
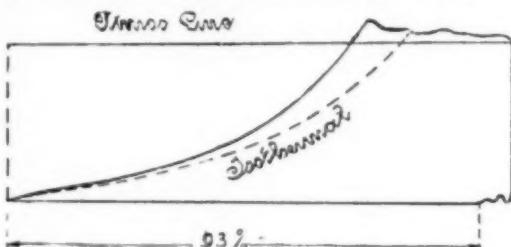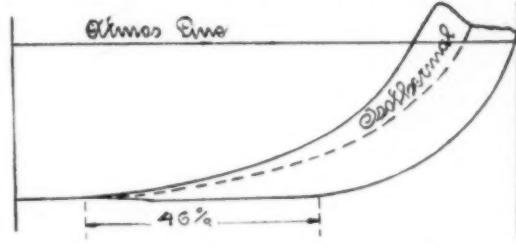
FIG. 3.—INDICATOR DIAGRAM WITHOUT EQUALIZATION OF PRESSURE.

46 per cent on the pump without equalization of pressure. This is particularly important when working with a high vacuum, for here, with the necessarily high ratios of compression, it is sometimes the case that an air pump without equalization gives no suction effect at all; in other words, the efficiency is zero.

For very high vacua, up to 0.02 in. of mercury absolute pressure, the manufacturers recommend the adoption of the two-stage air pump, in which each cylinder is of the same design and dimensions as the cylinder of the standard single-stage pump. The two-stage pump is arranged so that the second cylinder draws the air from the first cylinder, compresses it, and discharges at atmospheric pressure. No compression, therefore, takes place in the first cylinder, and by this design a very high vacuum is obtainable.

This pump is now being used with marked success in many of the more important incandescent lamp factories both here and abroad. Mr. J. W. Sittig, of Temple Court Building, New York City, is the American representative.

French Bauxite.

Red French bauxite contains about 60 per cent to 63 per cent of alumina, about 20 per cent of iron, while the silica contents are less than 2 per cent. This red bauxite is used principally in the production of alumina for the manufacture of the metal aluminium. In the refining process of this red bauxite the high percentage of iron is not objectionable, while a high percentage of silica content is almost fatal to economical manufacture.

Bauxite of this character seems to be only found in large quantities in the South of France in districts extending from the province of Var, near Toulon, in a westerly direction toward the foot of the Pyrenees. A number of years ago the various bauxite properties were controlled by a great many small and irresponsible companies, but 10 or 12 years ago most of the best of these properties were acquired by the Société Anonyme de l'Union des Bauxites de France. This company has supplied nearly all the imported bauxite which has been used up to date for the manufacture of aluminium in this country. While the present sole producer of aluminium in this country is believed to have a virtual control of the American bauxite deposits which are suitable for the production of aluminium, it will be gratifying to those interested to learn that there are still huge quantities of the French bauxite of the quality best adapted for this manufacture which may be purchased by those desiring to enter the aluminium business now that the basic patents have expired. The Continental-American Ore Company, of 33 Broad Street, Boston, Mass., have the American agency for this red French bauxite.

Titanium-Steel Rails.

In our March issue, page 128, we published an interesting article by Mr. Charles V. Slocum on the use of titanium in steel for rails, wheels, etc. Since, after all, the proof of the pie is in the eating, the adjoining comparative photographs of standard Bessemer and titanium-treated steel after simultaneous use under heavy traffic are decidedly interesting.

On Oct. 7, 1908, 24 rails were placed in service for comparative trial on Kesslers Curve, Cumberland Division, B. & O. Railroad. Seventeen of these were treated with titanium alloy, the other seven were plain standard Bessemer.

These rails were placed on both the high and low sides of this 9-deg. curve, which is in almost constant use under heavy

FIG. I.—KESSLERS CURVE. LOWER LEFT-HAND RAIL TITANIUM-STEEL. LOWER RIGHT-HAND RAIL STANDARD BESSEMER.

traffic. Photographs were taken on July 8, 1909, exactly nine months from the date these rails were laid.

All of the 17 titanium rails were then in excellent condition. In Fig. 1 the lower right-hand rail is standard Bessemer steel, the lower left-hand rail titanium-treated steel. The difference is indeed very remarkable. In Fig. 2 the lower rail is of standard Bessemer steel.

At that time diagrams were also obtained directly from the rails by R. W. Hunt & Company, engineers, New York and Chicago, showing that the loss by wear from the Bessemer

FIG. 2.—KESSLERS CURVE. LOWER RAIL STANDARD BESSEMER.

rails, in pounds per yard, was 294 per cent greater than from the titanium rails.

Concerning the later behavior of these rails, some interesting statements were made at the meeting of the Rail Committee of the American Railway Association in Niagara Falls on Monday, Oct. 4, by Mr. W. A. Thompson, engineer of maintenance of the B. & O. Railroad. He stated that all the titanium rails placed on the track on Kesslers Curve, Oct. 7, 1908, were still in service in good condition and had now shown more than 300 per cent increased durability over the standard Bessemer rails; these original titanium rails are now competing

against the second set of standard Bessemer rails; the first set of the latter having been worn out and removed.

At the same meeting Dr. P. H. Dudley confirmed the remarkable showing of titanium-steel rails, as sketched above, on the basis of the results obtained on the New York Central lines.

For the two photographs and for the above information we are indebted to Mr. Charles V. Slocum, the Pittsburgh representative of the Titanium Alloy Manufacturing Company, producers of ferro-titanium at their Niagara Falls works under the patents of Mr. A. J. Rossi, the indefatigable pioneer of the titanium industry. They also produce titanium-copper.

Chemists' Slide Rule.

The Scientific Materials Company, of 717 Forbes Street, Pittsburgh, Pa., has placed on the market a slide rule designed especially to reduce the time required for the calculation of chemical analyses to a few seconds, and at the same time to increase the accuracy of the results. The calculations for which it serves include multiplication, division, and the determination of various powers of numbers. The extraction of roots is also possible, but is a little more complicated.

The ordinary slide rule is now such a familiar and absolutely necessary device, used by engineers all the time, that there is no necessity of explaining its principle besides stating that it is a mechanical substitute for voluminous logarithmic tables and of sufficient accuracy for all practical calculations.

The chemists' slide rule is based on exactly the same principles as the old original slide rule, but it differs only in so far as it has certain marks especially useful in chemical calcula-
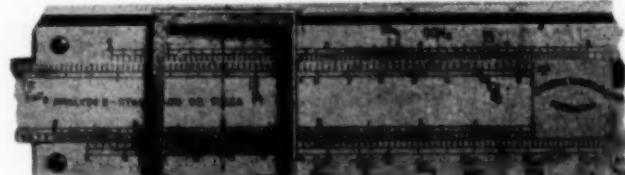
CHEMISTS' SLIDE RULE.

tions. The chemists' slide rule consists of a bar of mahogany having a tongue or slide moving in a groove along its center and a metal frame having a glass plate, which by means of a finely ruled line aids in making readings. Part of the chemists' slide rule is shown in the adjoining illustration.

As it is well known, the ordinary slide rule is particularly suitable for the calculation of proportions. And this is the reason why the chemical slide rule is so useful in any calculation of analyses. This involves the use of proportions and may be expressed by the equation $FP \div S =$ percentage, in which F is the factor, P is the amount of substance found, and S is the quantity taken. As the factors are constant numbers, they have a fixed place on the slide rule, and are indicated by a mark on the scale. This makes the use exceedingly simple. Certain elements are determined in different forms of combination and have consequently different factors. The marks corresponding to the factors are placed above the logarithmic divisions in order not to cause confusion.

In the case of elements or atomic groups, which are always determined in one and the same form of combination, for example, carbon as CO_2, hydrogen as H_2O, there is entered in large letters along with the factor the symbol of the element or atomic group. In the case of elements which may be determined in different forms of combination the symbols of these different forms are expressed by smaller letters. The fact that these important factors do appear distributed both on the rule and on the slide promotes the clearness and facilitates the readings.

To those who are familiar with the slide rule, its eminent

usefulness for chemical calculations will be evident. There is, of course, required a certain familiarity with its use, but, as any engineer can testify, this familiarity is very quickly acquired by constant use. There seems to be no reason why the slide rule should not become as indispensable for the chemist as it has been in the past for the mechanical and electrical engineer.

Notes

Conical Mills.—We have received an interesting little model of the conical ball and pebble mill manufactured by the Hardinge Conical Mill Company, 39 Wall Street, New York City. This mill was described and illustrated in our January issue of this year, page 47. The model is 3 in. diameter, made of glass and mounted on an aluminium base. It is partly filled with sand, beads, and pebbles, of various sizes, and the transparent construction shows very neatly the peculiar sorting process by which the different pebbles arrange themselves according to their size. No matter what the initial arrangement may be, a dozen turns or so are sufficient to collect the fine ground product at the discharge end of the cone.

Nichrome Resistance Wire.—In the field for resistance wires for electric heating apparatus, many efforts have been made to find some alloy that has the eminently desirable features of platinum and yet can be produced at a lower cost. The Driver-Harris Wire Company, of Harrison, N. J., are now manufacturing a nickel-chromium alloy under the trade name "Nichrome" which promises to solves this perplexing problem. This wire is exceedingly satisfactory for use in laboratory electric furnaces, pyrometers and thermo-couples, and electric heating specialties in general. The resistance per mil foot is 575 ohms and the temperature coefficient 0.00024 per degree Fahr. We have seen a sample of this wire which had been continuously run in air at 1500° Fahr. for three months, and then left exposed to the fumes of a chemical laboratory for some months longer. No deterioration was evident and the wire appeared to be as good as new. In a shorter test a temperature of 2500° Fahr. in the open air was obtained without any trace of deterioration.

Wrought-Steel Floor Plates.—Some interesting comparisons of wrought-steel and cast-iron floor plates for floors and stairways in engine and boiler-rooms, factories, power plants, etc., are given in a recent folder issued by the Keystone Steel Co., of Warren, Pa. Wrought-steel plates are useful for all inside and outside work where, besides handsome appearance, a roughened surface is desired to prevent accidents from slipping, to resist wear and to insure a safe and light construction at a low cost. "Diamond," "ribbed" and "checkered" patterns are gotten out under the trade name "Kesco," and are made in various sizes up to 72 in. x 120 in. and from ⅛ in. to ¾ in. thickness. The advantages claimed are: 50 per cent stronger than cast iron, 30 per cent cheaper than cast iron, and freedom from accidental breakage. These wrought-steel floor plates are made from finest open-hearth boiler steel.

Steel Mill Machinery.—Among the neatest of new catalogs we have received is one by MacKintosh, Hemphill & Company, Fort Pitt Foundry, Pittsburgh, Pa. There are introductory notes on the history and the present manufacturing facilities of the company, with a view of the works and views of the machine shop. The rest of the book is divided into sections on: 1. Rolling mills for blooms, plates, rails, sheets, etc. 2. Engines, simple, reversing, blowing and air compressors. 3. Miscellaneous machinery for iron and steel works, including shears, saws, cambering machines, hydraulic presses, accumulators, riveters, punches, flywheels, etc. There are some eighty-seven pages of admirably executed half-tone cuts giving elevations, plans, and sections, and the book as a whole fittingly represents one of the old-time and yet modern and progressive foundries of the Pittsburgh district.

Digest of U. S. Patents.

Electric Furnaces (Continued).

640,283, Jan. 2, 1900, Francis E. Hatch, of Norway, Mich.
Resistance type. The furnace is a short horizontal cylinder of fire clay, closed at its ends and mounted to rotate on a central shaft projecting from one end. The heating of the charge is effected by a series of 96 carbon resistors, secured to the inner face of the cylinder, there being six longitudinal rows of 16 carbons each. The resistors of each row are supplied with current and thereby heated as they descend, with the rotating cylinder, beneath the charge. The current is maintained on them while they pass beneath and until they rise from and again leave the charge at its opposite side. The electric current is fed successively to the six rows by a six-part commutator. The furnace is especially designed to smelt a mixture of iron ore, a reducing agent, such as carbon, and a flux of lime.

The cylinder may be revolved continuously or intermittently, the ore tumbling over and covering the lowermost resistors.

641,552, Jan. 16, 1900, Marcus Ruthenburg, of Philadelphia, Pa.
Resistance type. A body of fine ore or concentrates, e.g., magnetite, is agglomerated into porous lumps by heating a body of it until the contiguous corners of the particles fuse and adhere. The furnace is a graphite crucible serving as cathode and receiving a depending carbon rod anode. To agglomerate magnetite comminuted to pass a screen of 40 meshes per inch, the current density is 1000 amp per square inch of anode surface, at a voltage of 10 to 20, the current being maintained for five minutes.

641,976, Jan. 23, 1900, Robert H. Laird, of Pittsburgh, Pa.
Arc type. A stack furnace for smelting gold and silver ores. The furnace is surrounded by a water jacket and has a bell- and hopper-charging mechanism at the top. A series of downwardly inclined rod electrodes pass through the side walls, being arranged in two helical opposite rows. A series of pipes for air or steam enter the top of the furnace and a flue for gaseous products leads from the bottom to a "gas tank." This tank has an exhaust fan and a water-sealed outlet. The tank may be replaced by a zigzag pipe surrounded by a cooling medium and connected through an exhaust fan to a gas-storage chamber. Three delivery pipes, with cocks, lead from the bottom of the furnace at different heights. A pipe serves to introduce water for cleaning the furnace. In operation, the air or steam injected at the top of the furnace causes a down-draught and increased combustion, expelling the gases into the storage chamber.

643,254, Feb. 13, 1900, Albert Johan Peterson, of Notre Dame de Briancon, France, assignor to the Société des Carbures Métalliques, of Paris, France.
Resistance type. Especially designed for the manufacture of calcium carbide. The furnace comprises an upper fixed portion receiving the charge mixture and a lower movable portion, containing the resistor—a rectangular layer of molten carbide beneath the ends of which are carbon contact plates of opposite polarity, carried on iron plates or bars. Heating flues extend through the upper part of the furnace, receiving the waste gases from the smelting zone, burned by air introduced through suitable ports. The lower movable part of the furnace has air spaces and channels for cooling the electrodes and hearth. The furnace is operated continuously, the raw materials being charged in above and carbide discharging through a tap-hole. In starting, current may be initially passed between the contact plates through a layer of carbide in small pieces, or through a core of carbon, which disappears during the smelting.

NEW BOOKS.

STEINMETZ, CHARLES P. Theoretical Elements of Electrical Engineering. 455 pages. Price, $4 net. New York: McGraw-Hill Book Company.

STEINMETZ, CHARLES P. Radiation, Light and Illumination. 305 pages. Price, $3 net. New York: McGraw-Hill Book Company.

McALLISTER, ADDAMS STRATTON. Alternating-Current Motors. Third edition, revised and enlarged. 334 pages. Price, $3 net. New York: McGraw Hill Book Company.

FRANLIN, W. SUDDARDS, AND ESTY W. Dynamos and Motors. A text-book for colleges and technical schools. Direct-current and alternating-current machines. 497 pages. Price, $1.40 net. New York: Macmillan Company.

LEA, F. C. Hydraulics for Engineers and Engineering Students. 548 pages. Price, $1.50 net. New York: Longmans, Green & Company.

UNWIN, W. CAWTHORNE. The Elements of Machine Design. Pt. I. General principles; strength of materials; journals and shafting; couplings; pedestals; transmission of power by gearing, belting, ropes and chains. New edition, revised and enlarged. 545 pages. Price, $2.50. New York: Longmans, Green & Company.

TRAUTWINE, J. CRESSON. Trautwine's Civil Engineer's Pocket-Book. Nineteenth edition, revised and enlarged. By J. C. Trautwine, Jr., and J. C. Trautwine, 3d. 1300 pages. Price. $5 net. New York: John Wiley & Sons.

BOOK REVIEWS.

Abhandlungen der Deutschen Bunsen-Gesellschaft. Nr. 1. Uber die Erhaltung der Masse bei chemischen Umsetzungen. By H. Landolt. 47 pages. Price, 1.80 marks (retail price in New York, 60 cents); price for the members of the Bunsen Society, 1.00 marks. Halle a S.: Wilhelm Knapp.

The German Bunsen Society, at its convention last year in Vienna, decided to venture upon a new form of publication, besides its excellent and well-known semimonthly journal, the *Zeitschrift für Elektrochemie*. The scheme of the new form of publication is to issue at irregular intervals pamphlets of a larger size than would be suitable for publication in article form in a periodical journal.

These pamphlets are to represent the results of extended investigations which have led to definite results. They are to be, therefore, in the form of monographs. In the same may be repeated what has been published before, but the chief object is to give a concise definite statement of the latest results obtained. The society intends to be very careful in accepting monographs for this serial. Besides the editor, Pröf. F. Abegg, one of the members of a special committee (consisting of Profs. Nernst, LeBlanc, Foerster, and Elbs) must vouch for the scientific value of the monograph.

The scheme is excellent, and the first number, which has just been issued, shows clearly what is intended. In the first number a summary is given of the extended researches carried out by Prof. H. Landolt during the past 18 years on the question whether the fundamental principle of the conservation of mass in chemical reactions is absolutely correct. The investigations were made with greatest care, and from the summary of the results it appears that the experimental discrepancies from the above principle were one-half in one direction and the other half in the other direction and practically below the error of measurements. The principle of the conservation of mass may, therefore, be considered as having been established with the greatest accuracy now obtainable.

In spite of the fact that this result is of anything but a revolutionary character, the study of Landolt's long-extended researches will be found very interesting.

We wish the Bunsen Society godspeed in this new enterprise and trust that the following monographs will be of equal value as the first one.

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Text-Book of Physics. Edited by A. Wilmer Duff, D.Sc. Second edition, revised. 698 pages, 325 illustrations. Price, $2.75 net. Philadelphia: Blakiston's Sons & Company.

This excellent manual of physics is arranged in seven sections, which have been prepared by six different writers who are professors of physics. The sections and writers are: "Mechanics and the Properties of Matter," Dr. A. W. Duff, Worcester Polytechnic Institute; "Heat," Dr. K. G. Guthe, University of Michigan; "Wave Motion" and "Light," E. Percival Lewis, University of California; "Electricity and Magnetism," Dr. Arthur W. Goodspeed, University of Pennsylvania; "Electromagnetic Induction," Dr. A. P. Carmen, University of Illinois; "Conduction of Electricity Through Gases and Radio-activity," Dr. R. K. McClung, Mount Allison University.

A review of the first edition of this book was given on page 98 of our February issue. For the second edition the section relating to wave motion has been completely rewritten, and certain minor changes have been introduced in other sections. A change has been made in the typographical arrangement so that the fundamental facts are presented in large print and the features of secondary importance are discussed in fine print. This arrangement renders the book better adapted for class work at the various universities where it is used as a text. The very short time elapsed since the appearance of the first edition is a practical proof of the usefulness of the work.

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The Rise and Progress of the British Explosive Industry. Published under the auspices of the Seventh International Congress of Applied Chemistry by its Explosives Section. 418 pages, profusely illustrated. Price, $5.25 net. New York: Macmillan Company.

At a preliminary meeting of the Committee of the Explosives Section of the Seventh International Congress of Applied Chemistry, held this summer in London, it was proposed by Mr. Oscar Guttmann, and carried unanimously, that a history of the rise and progress of the explosive industry in the British Isles should be compiled. A publication subcommittee was formed consisting of Captain T. C. Tulloch, Major Cooper-Key, Mr. Oscar Guttmann, and Dr. W. R. Hodginson. Mr. E. A. Bragley Hodgetts was appointed editor.

The outcome of this committee's work is a most handsome, beautifully illustrated and intensely interesting volume, embodying a vast amount of information in most convenient form. Mr. T. G. Tulloch is right to say in the preface that posterity is under obligation to Mr. Guttmann, to whom the book owes its inception, and to his coworkers, because in years to come this book will be looked upon as a work of reference connecting the past with the future, for it is the only work of the kind containing so complete a history of the manufacture of explosives, not in Great Britain alone, as might be inferred from the title, but in general.

The bulk of the book contains historical sketches on the history of gunpowder (E. A. B. Hodgetts), researches on gunpowder and nitrocellulose (G. W. McDonald), nitro-glycerine and permitted explosives (H. de Mosenthal), percussion caps (E. W. Hulme), Bickford's safety fuse (G. J. Smith), military fireworks (J. R. J. Jocelyn), pleasure fireworks (P. Pain), legislature (E. A. B. Hodgetts), followed by a full bibliography, a most excellent chronology of the explosive industry from 1242 to 1700, and a list of gunpowder makers up to 1800. The second part of the volume contains concise descriptions of existing government and private explosive factories in Great Britain.